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KRUPP'S STEEL WORKS

BY

FRIEDRICH C. G. MÜLLER

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KRUPP'S STEEL WORKS

KRUPP'S STEEL WORKS

BY

FRIEDRICH C. G. MÜLLER

WITH 88 ILLUSTRATIONS BY
FELIX SCHMIDT AND ANDERS MONTAN

AUTHORISED TRANSLATION FROM THE GERMAN

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CONTENTS

CHAPTER | PAGE
I. Site and First Impressions 1
II. The Products of the Factory 6
III. What the Factory Consumes 9
IV. Entrance into the Works 16
V. Iron and Steel, and their Physical Qualities 21
VI. Iron and Steel as Chemical Compounds 25
VII. Steel and Iron Puddling 29
VIII. The Cast-Steel Foundry 36
IX. The Siemens-Martin Process 44
X. The Bessemer Process 53
XI. The Steam-Hammers 60
XII. The Rolling-Mills 70
XIII. The Armour-Plate Rolling-Mill and the Press House 74
XIV. Some Large Auxiliary Works. The Administration 84
XV. The Machine Shops 91
XVI. Krupp's Guns 97
XVII. Projectiles and Powder Charges 117
XVIII. Krupp's Proving-Ground near Meppen 134
XIX. The Benevolent Institutions of Krupp's Cast-Steel Factory
The System of Relief Funds:
Workmen's Widows and Orphans Pension Fund; Krupp Workmen's Aid Fund; Employés' Widows and Orphans Pension Fund; Life Insurance Association of Employés; Economies of Workmen; Krupp's Endowment Fund . . 153

CONTENTS

CHAPTER PAGE

XIX. The Benevolent Institutions of Krupp's Cast-Steel Factory—*continued*

Workmen Colonies:

Kronenberg; Schederhof; Dreilinden; Ménage; Lodging-house for unmarried Employés; Altenhof 161

Supply Stores 171

Hygienic Precautions 179

Krupp's Schools:

Public School; Industrial School; Housekeeping School . 182

SUPPLEMENT: The Factory in the Spring of 1897 190

CHAPTER I

SITE AND FIRST IMPRESSIONS

WITHIN a few German miles of the Rhine, north of the river Ruhr, in fertile, undulating, yet not attractive country, sur-
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For

"At the time of his death the number of employees and workmen in and near Essen was 45,000"

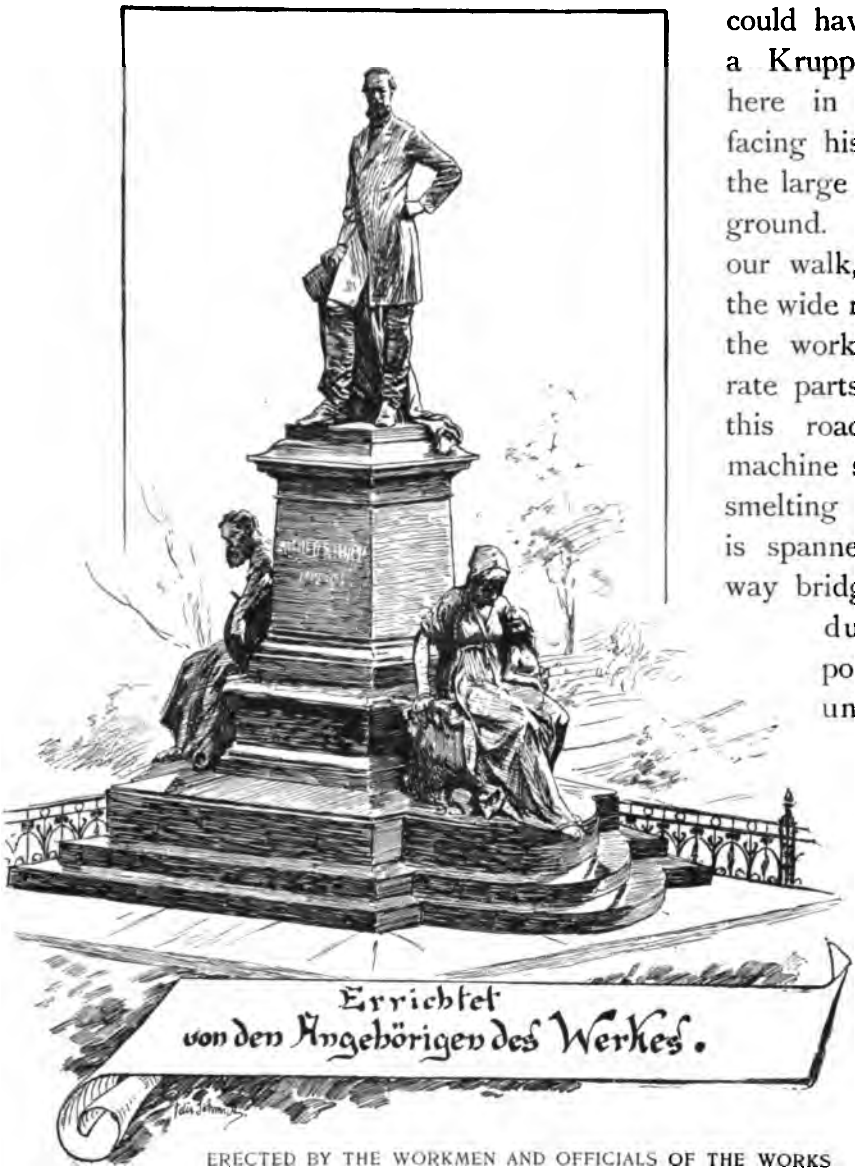
Read

"At the time of his death the number of employés and workmen, with members of their families, in and near Essen was 45,000, and including all those occupied in the mining and smelting works lying outside Essen, his realm embraced 75,000 souls."

The town of Essen has erected this life-like statue, in grateful commemoration for generations now and to come of her most distinguished son. For this man, sprung from an old and honourable family of Essen, within the time of half a generation, raised that small unknown country town to its present importance and celebrity. He did not sit in the council of aldermen, but in the small steel foundry inherited from his father, with barely a dozen workmen, he, a mere youth, began the battle of life, and only after hard and prolonged struggles did he win the victory. Krupp's steel foundry rose to world-wide fame, and grew beyond all limits. At the time of his death the number of employés and workmen in and near Essen was 45,000, and including all those occupied in the mining and smelting works lying outside Essen, his realm embraced 75,000 souls. Small wonder that the town adjoining Krupp's factory and the whole neighbouring district developed with great rapidity.

As we mentally review the industrial exploits of this man, it seems to us that his monument standing here before the town-hall is scarcely amid its proper surroundings. Large and small shops are on both sides of it, but none of his giant chimneys. Only the more observing visitor will even here detect the proximity of the great factory ; low thuds, now and then a muffled detonation, and the yellow and grey clouds of smoke which float through the air, revealing its nearness. Following the crowd, and turning to the east, we descend a busy street well set with gay shop windows, cross a square shaded by linden trees, and find ourselves on Krupp's territory. His hotel, its adjoining garden, the picturesque wooden structure of the Casino, the gymnasium and fencing-hall for the use of employés, are on the left ; on the right stands the large industrial school ; straight ahead lies the ever busy market, and the Krupp slaughter-houses ; beyond them is the forest of smoking and steaming chimneys.

A few steps farther on a wide gap opens in the rows of houses, and we see before us the beautiful new monument which the employés and workmen of the factory, only a few years since, erected in memory of their master. This statue is the work of the Munich sculptors Menges and Aloys Mayer. Krupp's bronze figure, very similar in its attitude and accessories to the one before the town-hall, stands on a high granite pedestal, and is flanked by symbolical figures ; on one side is a muscular smith, holding in his right hand a sledge-hammer, while his left rests on a railway car wheel, a cannon lying near his feet. On the other side, a group represents a workman's widow and child, the mother looking with quiet confidence at a scroll bearing Goethe's words, "Man, be noble, helpful and good," alluding to the humanity with which Krupp protected the widows and children of his workmen against want and distress.


Errichtet
von den Angehörigen des Werkes.

ERECTED BY THE WORKMEN AND OFFICIALS OF THE WORKS

Hardly a better place could have been found for a Krupp monument than here in the main street facing his works, and with the large bazaar as a background. Let us continue our walk, passing through the wide road which divides the works into two separate parts. Both sides of this road are lined by machine shops, forging and smelting houses, while it is spanned above by railway bridges and big conduits. A row of portals guarded by uniformed doorkeepers allow us glimpses into the streets and yards within. At the main entrance we see a tablet bearing the disappointing notice, "No admittance."

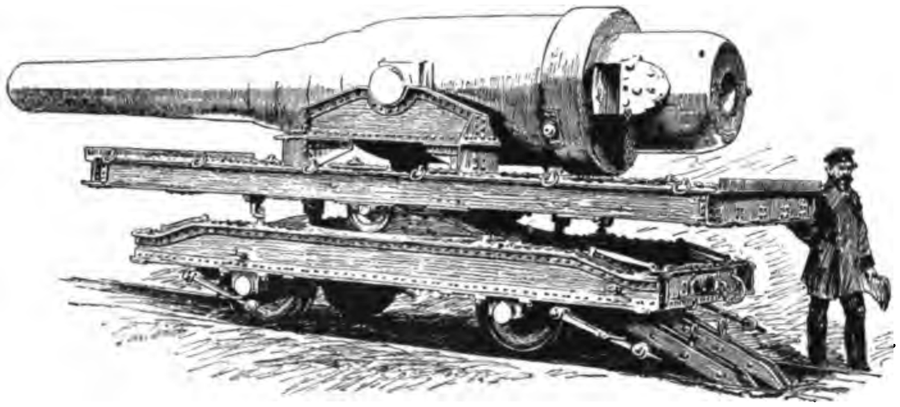
Many a curious traveller may have eagerly gazed at the lofty chimney "Fritz," ascending like a lighthouse to the height of 100 metres, have listened with resignation to the noise of the engines, and the pounding of the steam-hammers, while counting the great puffs of reddish smoke which rise with every charge of the Bessemer furnaces. It takes a quarter of an hour's brisk walking to reach the other end of the factory. The road presents its most lively and interesting picture soon after the beginning of the recess for the mid-day meal. Even before the steam whistles give the signal, the gates are crowded by women and children bringing dinner to the men employed in the furnace-room, where the work cannot be interrupted. The machine and other departments pour out their army of men, and the road seems hardly wide enough to hold them all.

AT THE GATE

From Krupp's water-tower or from the upper gallery of the gasometer we get a fine panoramic view of the works. It is one which makes an almost overpowering impression on every thoughtful mind; an impression which, although of a different nature, yet vies with that produced by the snow-clad Alps or the beautiful Gulf of Naples. Is there not a fascination in seeing the life and activity of mankind, the flood of traffic in a commercial centre, the forest of masts in a great harbour, and in the sight of a great factory, of which the many chimneys almost appear to support the clouds? We realise man's greatness in mastering the forces of Nature, and our hearts beat with just pride. Also, the panorama which lies before us is not wanting in picturesqueness, while its colouring is rendered vivid by the contrasting hues of smoke and steam, the occasional upward shooting flames, and showers of glowing sparks. At night a nebulous light envelops the whole scene, volumes of steam reflect the red and yellow fires, and rays of light flash forth from windows and skylights. The writer has seen many great smelting establishments of Europe at night and in broad daylight; has been in Sheffield and in Newcastle, and must admit that nowhere else has he received so intense an impression as in Essen. Here is no irregular gathering of sheds and workshops; buildings of vast dimensions give the picture an air of stability and grandeur.

And from where we stand we need only turn round in order to contemplate another interesting sight. A large quiet town, regularly laid out with broad streets planted with tall linden trees, and lined by solid three-storeyed dwelling-houses with well-kept gardens, forms a scene which speaks of happy homes and family life. This is Krupp's colony, Cronenberg, containing over 8000 inhabitants. More to the left lie two smaller colonies numbering in all 1000 homes. More than 25,000 people depending for their support on the factory live in Krupp's houses.

These systematically built colonies, and the numerous institutions for the welfare of the workmen, the data of which are given at the end of this book, tell in language which cannot be misunderstood, that the maker and master of this gigantic factory provided like a father for his workmen and employés. And this humane spirit has been inherited by his son, the present sole proprietor of the works. Krupp's people have resisted the influence of modern teachings as to the "rights of the disinherited," have retained the sentiments of affection and gratitude, and in a clear and simple manner have preserved and expressed these sentiments, by the erection of his monument and by the words of their speakers. This inspires one with confidence that for a long time to come all the members of this great and powerful community, from the highest to the lowest, unanimous in faithfulness to their duties, will continue to bear Krupp's banner victoriously aloft for the admiration of the world and the honour of the fatherland.



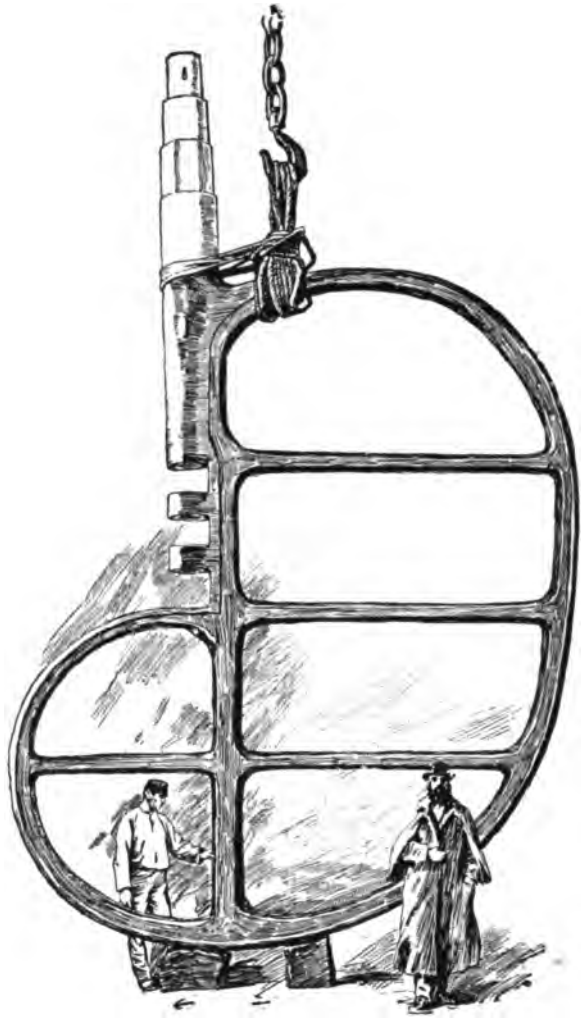
TRUCK FOR THE TRANSPORT OF ORDNANCE

CHAPTER II

THE PRODUCTS OF THE FACTORY

SUCH an army of workmen in this gigantic factory must of course produce an extraordinary quantity and grade of articles. As everybody knows, here is the birthplace of the modern cannon. Alfred Krupp has been dubbed "The king of cannons," for the cast-steel gun laid the foundation of his celebrity, and through the manufacture of this gun his factory at Essen grew and prospered. A modest six-pounder, shown in the London Exhibition of 1851, excited the admiration of experts. To-day there are issued from the factory, in addition to many field- and siege-guns, monster guns up to 120 tons, with steel gun-carriages, the ingenious mechanism and construction of which would enable a child to put them into motion. What extraordinary foundries to cast the necessary blocks of steel, what forges and hammers to change these blocks into cylinders fifty feet long, what tools to drill them so that a man might crawl through, to polish the bore, and to rifle it with such accuracy that its width does not deviate by a hair's breadth from the correct dimensions! Even the layman who has never seen an arsenal must be aware that it requires an uncommon degree of intelligence, energy and pluck to achieve such results. Also it must not be forgotten that all the metallurgic processes, and all the mechanical appurtenances required for the manufacture of steel cannon were first thought out and put into practice at Krupp's works. Many years of hard labour and struggle had to be gone through before Governments could be made to understand what aggressive and defensive power is embodied in the cast-steel gun. Other establishments in other countries have now attained considerable success in the production of guns; but a fact which should not be ignored is that the first path to such success was cut more than two score years ago in Krupp's small workshop in Germany.

Although, all over the world, the name of Krupp is essentially connected with the modern high power cast-steel gun, the productive field of work at the Essen steel foundries extends far beyond that point. Next in importance stands the manufacture of projectiles. More shell and shrapnel can be produced in one week than were fired in the great battle of Königgrätz. Shell of much larger calibre than those wonderful field projectiles form an important speciality of Krupp's; we refer to his hardened steel shell which pierce heavy armour without shattering. The manufacture of these shell in many ways presents difficulties not less than those which must be surmounted in the manufacture of the guns from which they derive their power of penetration. In the Essen museum of projectiles may be seen a 24-centimetre (10-inch) armour-piercing shell, weighing 160 kilogrammes, which served in those trials


RUDDER-FRAME (STEEL CASTING)

of August 1879 on the Meppen proving-ground, which were the talk of the whole military world. This shell pierced 50 centimetres of solid iron and only touched the ground 2000 metres beyond the target. It seems almost incredible that it is the same shell, for it appears perfectly new, but a careful measurement will reveal a slight upsetting of the projectile. An important branch of manufacture at Krupp's is that of similar armour-piercing shell, made of the very best steel, hardened with the utmost care, and weighing up to 1050 kilogrammes.

Some years since, the factory began also to manufacture weapons of defence. In a vast new building, aided by the latest and largest metallurgic and mechanical appliances, it produces armour plates for men-of-war and fortifications. Success was first obtained in making excellent compound armour plates, consisting for about two-thirds of their thickness of tough homogeneous iron, and for the rest of a layer of very hard steel. At present certain alloys of iron and nickel render the best results in armour plates.

Cannon, shell, and armour plates are the specialities which make the name of Krupp famous all over the world; but it should not be ignored that a great number of his workshops are kept busied in the purposes of peaceful industry; and his steel foundry in this respect also occupies a prominent place among the steel factories of the world. While for details the reader is referred to following chapters, preliminary mention may here be made of steel forgings and steel castings of extraordinary dimensions as prominent specialities. Under this head may be enumerated anchors, rudders, stems for men-of-war and large merchant vessels; also wheels, shafts and cranks for the transmission of mechanical power.

Judging by the tonnage, the production of railroad material such as rails, switches, tyres, wheels, axles and springs takes the first place.

The factory also turns out a great quantity of high grade steel for making tools and instruments of all kinds, for its own use, as well as for sale.

COLLIERY: "HANOVER'

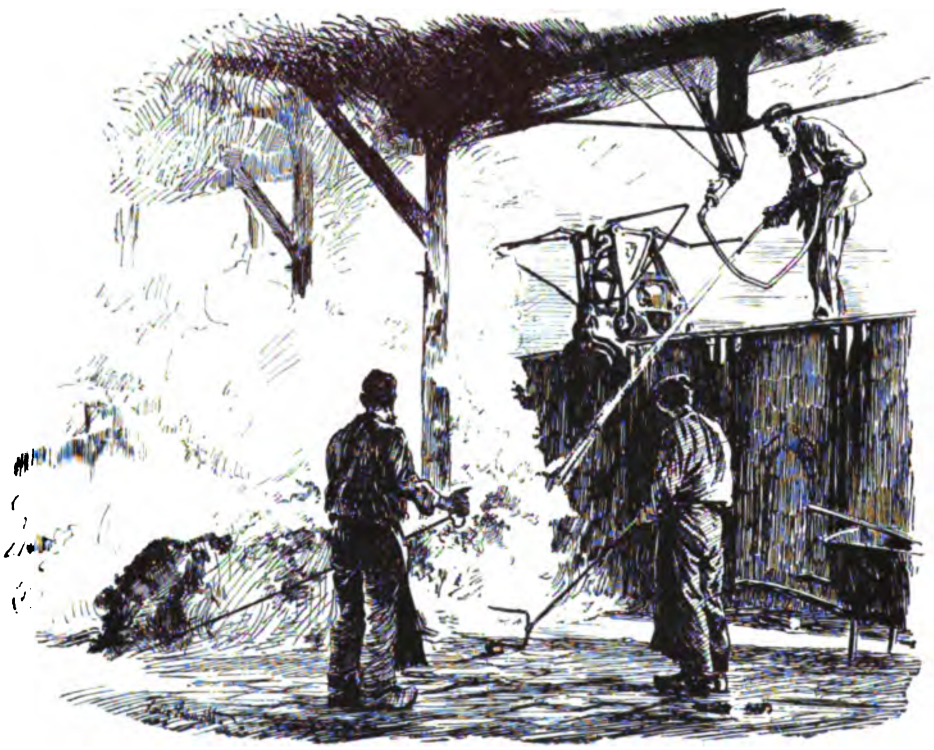
CHAPTER III

WHAT THE FACTORY CONSUMES

A FACTORY in full operation resembles a gigantic organism whose life is subject to the laws of nature, and whose ingenious and complicated organs move and exert themselves in obedience to impulses proceeding from an invisible intellect. The work of such an organism cannot come from nothing, it is the equivalent of another energy which it consumes. The working body must be fed.

Its nourishment is provided by fossils which were once living plants absorbing water, carbonic acid, and the radiant energy of the sun, to build themselves up; and which were then buried and changed into coal. This stored-up energy revives in contact with the oxygen of the atmosphere either through the slow process of oxidation or else quickly and powerfully by combustion—by fire, which man stole from the gods and made serviceable to his own ends. The possession of fire by man is one of the privileges which raise him above the animal, and the progress of civilisation keeps equal pace with the increasing use of fire. Combustibles are the nourishment from which a great factory draws its life and its power.

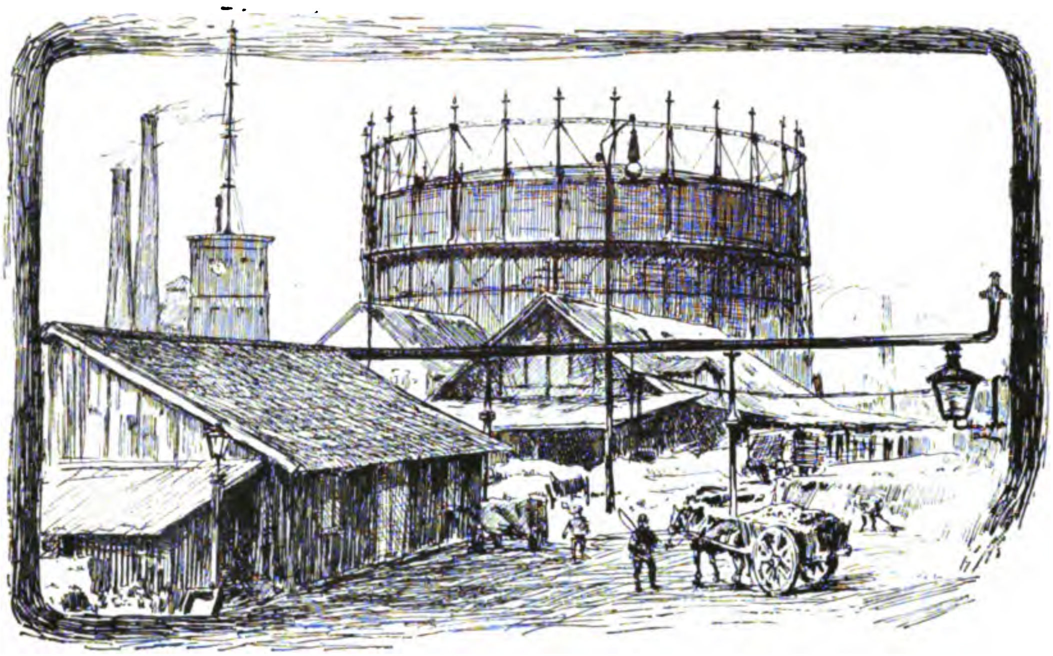
It is certainly very interesting to learn what quantity of coal and other raw material the enormous factory before the gates of which we have arrived requires to sustain its life. For its necessary provision of coal it is most advantageously situated. There is even a coal mine within its grounds, while two other collieries in the Ruhr district are the property of the firm. But these three mines do not fully supply the demand for combustibles, which for the steel foundry and its dependencies amounts to not less than 350 carloads of ten tons each per day, that is to say, in the



COKE OVENS

neighbourhood of one and a quarter million tons per annum, which about equals the average supply in Germany for one million of its population.

Most of the coal is consumed in its natural state; under the boilers, in furnaces, or in open fires. But a large quantity is also burned in the form of coke in shaft and blast furnaces, in the foundries and Bessemer works. Coke is coal freed from its gas by means of heat. It is made in the Ruhr district in large brick ovens heated from the outside. These adjoin each other in blocks, forming tunnels which can be securely locked by doors on both sides, and which are filled with coal through openings on the top. In these tunnels there is a system of pipes, in the walls and under the floors, arranged to receive the combustible gas escaping from the coal, and to conduct it to the boiler-rooms, where it is burned for heating purposes. As soon as the contents of one of the coke ovens are ready, its doors are opened, the entire volume of coke is pushed out by machinery and is immediately exposed to cooling jets of water. The firm owns in Essen and



GASOMETER

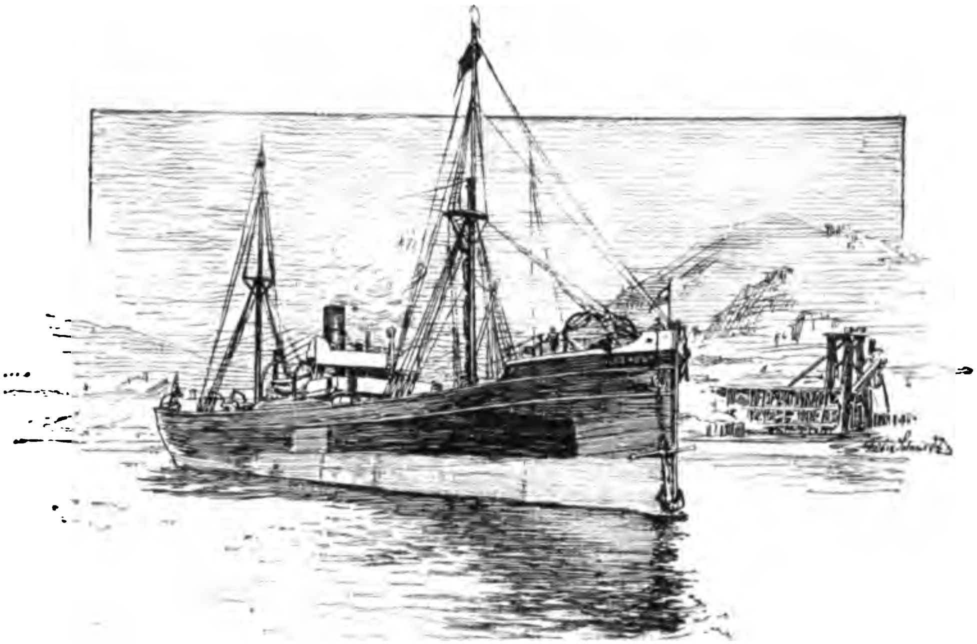
in its other works, altogether 549 of these ovens, which produce a daily average of 92 double carloads of coke suitable for smelting. We ought to mention, that, in order to diminish the percentage of ashes in the coke, every coking plant is connected with a large refining plant, where the coal is crushed and its impurities are separated by a washing process.

In preparing the coke, gas is used for heating purposes, while gas destined to be used for lighting is the chief product of a special gasworks. The gasometer and gasworks form a prominent feature in the panorama of the factory, and are large enough to provide a whole city with light. They supply more than 30,000 burners, consuming 13 million cubic metres of gas; as large an amount as is used in Stockholm or in Breslau. In addition to all these burners, the electric plant of the factory feeds 626 arc lights and 2000 incandescent lights.

So much for the combustibles which, when brought into contact with air and fire, develop the powers of this gigantic body and bring them into action. The necessary air is without much difficulty obtained from the atmosphere by natural, and in some instances by artificial, draught. To furnish the factory with the water, which is, so to say, required as a digestive fluid that first absorbs and then distributes energy, there has been provided an elaborate system of pipes and conduits, having hundreds of valves and faucets of all sizes. As a rule, natural pressure is not sufficient to drive the water through this system, and large pumping-plants do this part of the work. It is difficult to form an adequate idea of the quantity of water required. In 1892 to 1893 the amount used was 24,500 cubic metres (over 5,400,000 gallons) a day, averaging 285 litres (62½ gallons) per second; being rather more than the city of Dresden consumes. This shows that the waterworks alone represent a plant of the first order. The main pump, with its large engine of 1544 indicated horse-power, is situated on the river Ruhr, six kilometres (about four miles) from the centre of the factory, near the foot of the hill on which stands the "Villa Huegel," the princely home of the Krupp family. No traveller who visits Essen should omit making a trip to this spot, where he can rest comfortably at a Krupp Inn, standing amid lovely surroundings, on the shaded slope of the hill.

The upper reservoir of the waterworks is 110 metres above the level of the Ruhr; the total length of the pipes 200 kilometres or over 140 miles. Most of the water serves to feed the boilers. According to a statistical statement made in 1892, there are no less than 263 boilers in the cast-steel works in Essen, which, by means of 421 steam-engines of all sizes, develop 33,000 indicated horse-power, and move 111 steam-hammers, the rams of which add up to a total weight of 250,000 kilogrammes.

Such is the material drawn from the realms of air and of water which enters the factory, and by means of chemical and mechanical processes converts the solid raw materials into those products and half-products which civilised nations require for so many purposes.



A STEAMER OF KRUPP'S IN BILBAO HARBOUR

Pig-iron, in its many varieties differing from each other in physical and chemical qualities, is a half-product, obtained by artificial means from various iron ores mined in the depths of the earth. Mr. Alfred Krupp, in order to make himself as independent as possible with regard to the supply of pig-iron, purchased, as much as twenty or thirty years since, a number of mines and of furnaces. The firm now owns more than 500 mines in Germany, thirteen of which are fully equipped with complete mechanical mining-plants. In addition to these mines, the firm owns a partnership in large iron mines

BLAST FURNACES, "JOHANNISHÜTTE," NEAR DUISBURG situated near Bilbao, in Northern Spain. The hematites, celebrated for their extraordinary purity, which are obtained from these Spanish mines, are transported from Bilbao to the ports on the Rhine in four sea-going steamers owned by the firm. Three of Krupp's smelting-works, having each four blast furnaces, manufacture from 1800 tons of iron ore, 800 tons of pig-iron per day, an amount which about covers the demand of the Essen factory.

In addition to iron ore, other auxiliary raw materials are needed for the smelting-works, notably certain fireproof substances, such as clay, quartz, sand, graphite, limestone and dolomite. Some idea may be formed of the quantity of these required, from the fact that on the Essen grounds special factories of imposing size produce 115 tons of fireproof bricks and up to 2500 crucibles per day.

These auxiliary materials finally become slag and refuse. A great quantity of slag also is produced by the Bessemer and open-hearth process; about twenty carloads of ashes and slag—and this is a very formidable quantity—come per day, from the furnaces in the Essen factory. Altogether, not less than fifty carloads of such refuse must be collected from different parts of the works and dumped outside, an unavoidable although a very disagreeable burden, which devolves on all important smelting-works.

FIREMAN ON DUTY

CHAPTER IV

ENTRANCE INTO THE WORKS

GUIDED by a bird's-eye view of the grounds, and some printed statistics placed at our disposal, we have taken our bearings as to the general proportions of the factory, its production, and the nature and quantity of the raw materials necessary for this production. Now we are eager to pass through the gates, enter the premises, and leisurely examine the details within. We are prepared to find that a walk through the workshops, made with the endeavour to see, and in a certain degree to understand the proceedings inside and outside of all the different buildings, will occupy a week's time, and will also require us to employ all our physical strength, as well as all our mental capacity.

It was the writer's especial good fortune, as much as twelve years ago, to be allowed to see a great part of the factory, and that under the guidance of an excellent engineer. Although he had, in the character of an expert, visited several of Germany's large and celebrated steel works, the impression made on him by Krupp's steel foundries was so overpowering, that he was strongly tempted then to publish some account of this wonderful realm of steel. Since then he has paid it several visits, and, with much admiration and patriotic pride, has seen the gigantic plant grow and flourish with surprising vitality and with a perpetual rejuvenation; as if to fill the place of the Titan who went to his eternal rest on July 15, 1887, a number of others had arisen. He now proposes to depict the present condition of Krupp's cast-steel factory: he will do so briefly, and in language which may easily be understood, trusting that his enthusiasm for the task will enable him successfully to accomplish it. He will not take a newspaper reporter's point of view, judging it more advisable to give a plain, faithful account, treating as he does of an industrial establishment of world-wide fame, with a reputation to which flowery words could not add, and of which all educated men will be glad to have a reliable description.

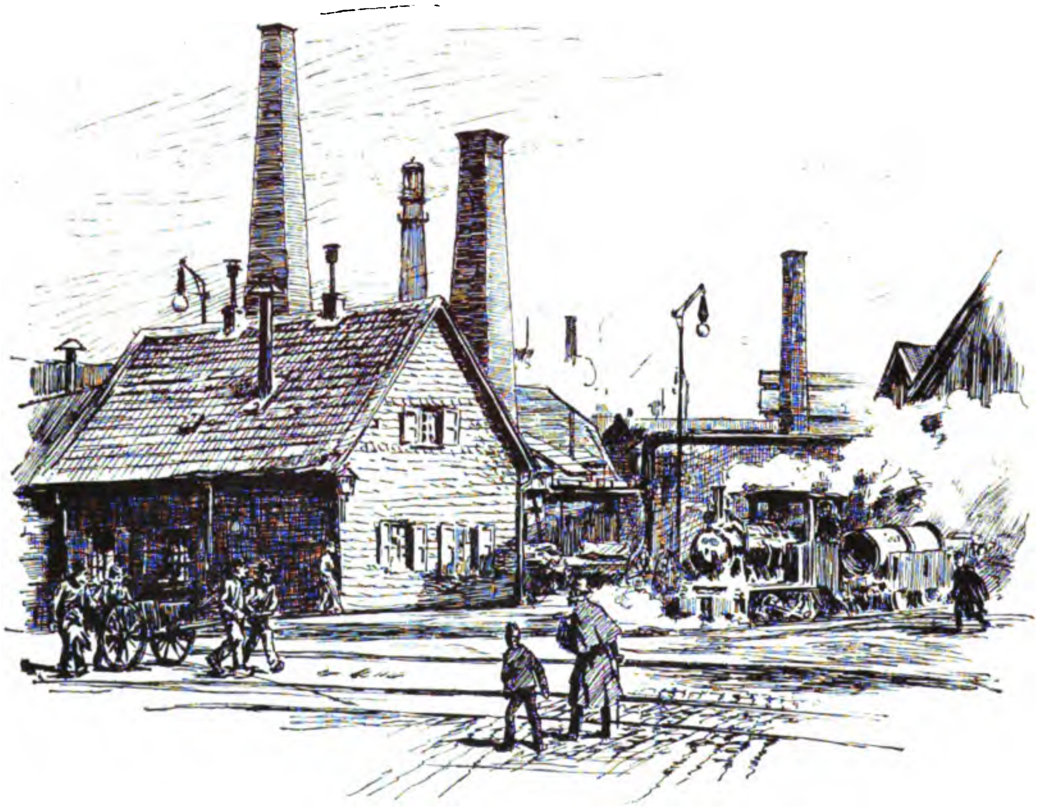
He does not intend to lead the reader through all these workshops for the mere purpose of sight-seeing and to satisfy only his curiosity, but also to let him know the ruling ideas and connections of them all, the aim and purpose of their arrangements.

This memorial will also furnish some simple information as to the metallurgy of wrought-iron and steel, touching, of course, only the essential points and omitting certain details which are professional secrets. But all that is said shall be accurate and to the point. To attain this end the writer has recently revisited all divisions of the works, where all necessary information has with great kindness been furnished him. His judgment has been formed from his personal inspection and experience; this fact, for the benefit of the experts who may read him, he deems important to state.

Let us now pass through the main entrance and, looking about us, walk for a time through broad, well-paved streets. Everywhere we see railway tracks running beside us, connecting all parts of the works with each other and with the outside world. Their total length is 80 kilometres, or 56 miles. We meet a long train of cars loaded with coal, and must stop to let pass us a small locomotive drawing a big block of steel from the foundry to the forge. Other railway cars and street cars are drawn by horses, thus lending variety to the peculiar life of these factory streets.

We soon reach our first stopping-place. It is only a little house, but we enter it with profound reverence. The cause for this feeling is explained by the following remarkable letter, written by Mr. A. Krupp to his board of directors:—

"*This small house, now in the centre of the factory, into which we moved in the year 1822 to 1823, after my father had, without success, sacrificed to the invention of the manufacture of cast-steel a considerable fortune, and* *besides that, his whole stock of vitality and health; this, then, the only dwelling of the family, where I have with them lived through a number of years of misery and sorrow; from whence in 1826, on the 28th of October, my father was carried to the grave; where, in the attic, in fear and trembling anxiety, with little hope for the future, I have passed hundreds of sleepless nights; where, before and after small successes, my first hopes awoke; and where I have lived to see the fulfilment of my boldest expectations—this small house shall (as soon as the season permits the work) be raised as much as is necessary, and put into exactly the same state that it was in originally. . . . I desire that it shall be kept intact as long as the factory exists, in order that my successors, like myself, may look with pleasure upon this memorial, this origin of the great works. This house*



KRUPP'S ANCESTRAL HOUSE

and its history may give courage to the faint-hearted and help him to persevere. May it prevent him from despising small things and preserve him from vanity."

No monument of bronze or marble could impress a visitor acquainted with the history of the works as does this family home, amidst its surroundings of large buildings of more recent date. From the gable window of the attic, where, when still almost a boy, young Alfred, anxious for the welfare of his family, worked all through so many a night, our eyes turn to the left, pass over the steel factory and rest on a large five-storeyed building—the administrative office of Krupp's kingdom of to-day—and at a glance we realise how much may be accomplished by a man in a lifetime of courage and perseverance.

"VILLA HÜGEL" AND THE WATER-WORKS

"*May this memorial encourage others who are in distress, may it strengthen their respect for humble homes, and their sympathy with the great sorrows which often dwell therein,*" are the words of Alfred Krupp.

After having devoted some serious moments to the memory of the founder of the works, who, seven years since, was taken from the little house to his final resting-place, we are anxious to enter the great foundry of crucible steel. Through the open gate we distinguish the outlines of a crowd of men, and, amongst them, a mass of brilliantly glowing sparks all moving in the same direction. But let us check our impatience and, before we enter, listen to a short metallurgical explanation, in order to enable us, intelligently and with added interest, to face the spectacle in store for us. It can scarcely be denied that, even among educated people, a knowledge of metallurgical processes is rarely found, and that despite the fact that our era is so often dubbed the "Iron Age," the vast domain of iron metallurgy is more especially a *terra incognita* to the layman. What is meant by the term "iron"? what by the term "steel"? This, before visiting a great steel factory, every one should endeavour to understand, for which reason we hesitate to enter the foundry, and will first go into the neighbouring laboratory, No. 11. In its locked closets there may be buried many a secret about steel-making which the outside world will perhaps never learn; but in its glass show-cases we may look at a large collection of samples amply illustrating what we are about to hear.

SMELTER

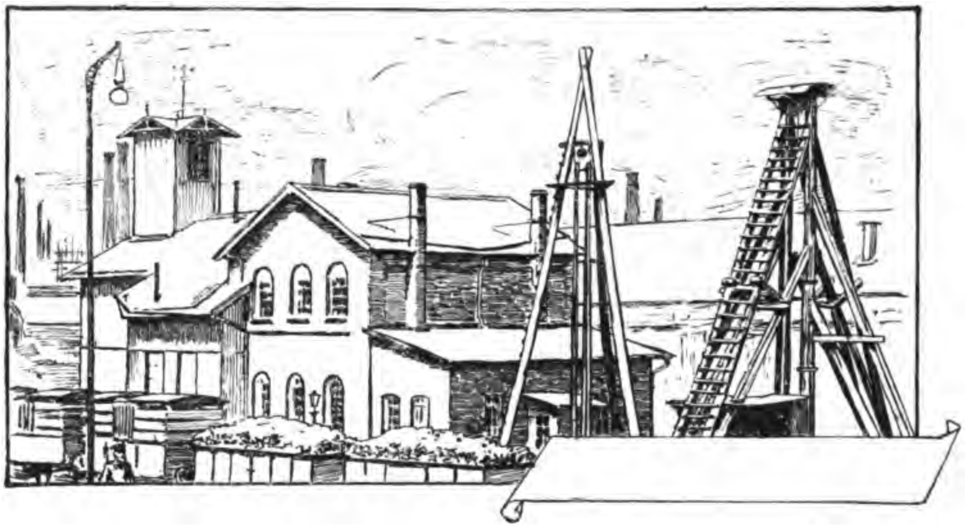
CHAPTER V

IRON AND STEEL, AND THEIR PHYSICAL QUALITIES

THE prominent part which the metals play in the development of civilisation is the necessary result of their peculiarly important qualities. In the struggle for existence they supply mankind with the best weapons, not best because of their brilliant appearance but because of their inherent virtues. A good steel sword is a very different thing from a stone mace or a stone hatchet, for not only is it hard and sharp edged, it is also elastic and tough, so that when blade meets blade it will not break. Why is not a cannon made of marble, or a ship's main shaft of wood? why is the gigantic Brooklyn Bridge suspended on steel wire cables? Because for such purposes a material is needed which can oppose to great pulling and compressing forces its superior powers of resistance. Such resistance is called "tenacity," and by it the engineer first judges the value of a metal. When to any large extent metals are used for resistant constructions, their tensile strength is tested in pulling carefully measured sample rods to pieces by mechanical apparatus which measures the strength applied for this purpose. Every such test also reveals two other important qualities—the elasticity and the "ductility" of the metal. As soon as the pulling force begins to act on the sample rod it undergoes an elongation, at first like a spring scales, *i.e.*, the elongation is double under double pull. But this "elastic" elongation is only very short and rarely reaches $\frac{1}{600}$ of the length of the rod under strain. When the pull passes a certain limit, a peculiar mobility suddenly seizes the molecules, and the rod begins to stretch considerably; this stretching quickly increases with increasing pull, and in some metals will elongate the rod to $1\frac{1}{3}$ its original length. This great elongation, after the limit of elasticity is passed, is an exclusive quality of metals, and gives the measure of their "ductility." Other materials, as, for instance, stone, which do not display this quality, are called "brittle." Near the point of rupture, especially with soft iron, a contraction of the cross section of the rod is observed, and the measure of this local contraction is by many engineers considered the best measure of its ductility.

One might suppose this mode of testing to be insufficient, because in practical use metal pieces are rarely acted upon by pulling force alone. Iron girders and rails are bent under their loads; shafts, transmitting the power of steam-engines to a distant place, must resist a torsional strain. In thousands of other cases they have only compressing forces to withstand. But we must remember that all these different kinds of tenacity are one in principle, and that they are proportional one to another. Tensile strength is the one which can be most accurately measured. But, in cases where scientific accuracy is not required, simpler tests are employed; as a criterion, for instance, of the quality of irons, workmen and foremen test them during the work by hammering and by bending. They judge of the ductility by hammering down a small piece on the anvil; if it flattens without cracking it is tough, if it cracks and splits it is lacking in toughness. That quality is of great value, because it guarantees security against sudden breakage, and also because it facilitates the shaping of metals by hammering, rolling or pressing. And it is a quality which in wrought-iron and steel is increased by heating the piece until it becomes quite soft, so that under great heat separate pieces can be joined together like wax. The facility with which iron can be welded, a quality equally important to the metallurgist and the smith, is one not found in other metals in common use.

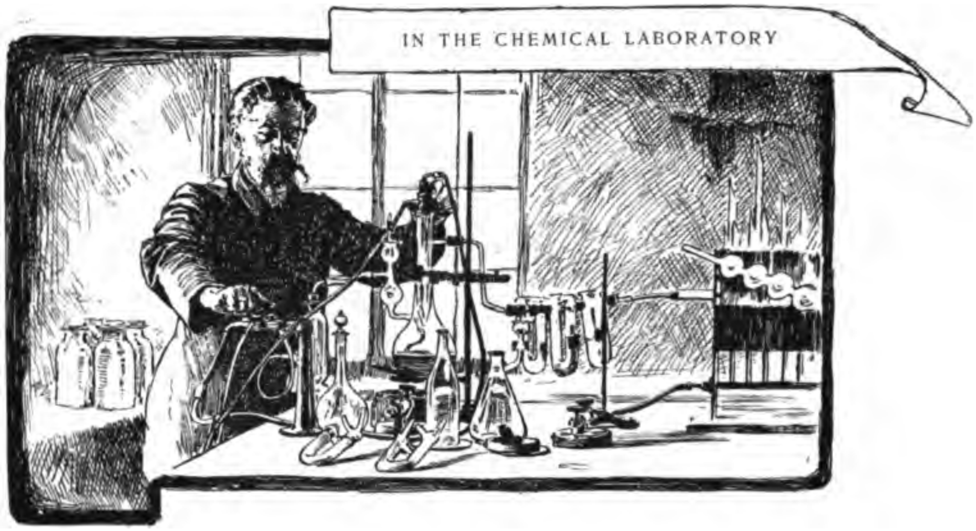
In addition to tenacity, ductility and elasticity, there remains another quality to be considered, which, although known to everybody, is still in a certain way enigmatic; this is hardness. This is shown when one tries to scratch a surface. We say that glass is harder than iron because we can scratch an iron surface with a piece of glass, and we cannot scratch glass with an iron nail. And for a similar reason we pronounce a steel file to be harder than glass. In this way we can in practice distinguish different degrees of hardness, but science does not possess a means by which to measure it and to express its value numerically. Hardness, often confounded with tenacity, or a high limit of elasticity, for the reason that it renders objects resistant against wear from friction or abrasion, is a very important quality; and above all is it requisite—be it intended to work in wood, stone, metal, or other substances—to every tool, from the needle of a seamstress to an armour-piercing projectile. Among all other metals in practical use, steel is distinguished by its great hardness, not a natural hardness, but an artificial hardness it obtains after having been heated red hot and then quenched in cold water. This faculty of hardening affords the best means of determining what is steel. Iron remains soft and tough, even after sudden cooling from a red-hot state.



TEST-HOUSE

It is unfortunate that, as a rule, brittleness accompanies hardness. An ideal metal ought to combine the tenacity and hardness of steel with the toughness of iron. In theory there is nothing to prevent the discovery of such a metal, and in practice its possibility has been demonstrated by some alloys recently made at Krupp's, and by Hadfield's manganese steel.

The above-named characteristic qualities, by which the value of every metal is determined, are continually tested and verified in all large steel works for the different branches of production. For this end they are provided with the necessary apparatus, especially with accurate testing-machines. Krupp's steel works possess a mechanical testing-plant which for great capacity and apparatus as well as for extent of work is perhaps unequalled. Managed by a trained engineer of many years' experience, it makes over 70,000 tests a year, comprising 25,000 for tensile strength. The amount of work done will perhaps be better appreciated if we add that every tensile test costs about 10*s*. As we do not wish to convey a false impression, we will here state that all well-established and well-conducted steel works have control over their manufacture to such a point, that only a comparatively small number of tests are really necessary to ensure the continuity of excellence in their product. The great majority of tests are made in order to satisfy customers, particularly the railroad administrations, who never weary of having tested by all the methods of scientific investigation even so simple and ordinary a piece of work as is a rail. This is especially true of German customers, and English or American manufacturers would scarcely credit what cost and trouble are caused to German industry, and what positive obstacles to its progress are often raised, by this so-called German thoroughness.


IN THE CHEMICAL LABORATORY

CHAPTER VI

IRON AND STEEL AS CHEMICAL COMPOUNDS

The fact that a metal of a distinct denomination can display such variety in its qualities as year after year to require thousands of costly experiments to test its mechanical qualities, can only be explained by the metal's being of changeable chemical composition, or, in other words, by its being an alloy. Pure, or very nearly pure metals are seldom used on a large scale. Every one knows that brass, bronze and German silver are alloys, but it is less generally understood that iron also is always alloyed with other elements, and that cast-iron and steel are the results of other elements which have to a certain percentage entered into an alloy with iron. Among all the different kinds of iron obtained by metallurgical process, only the very best wrought-iron and so-called homogeneous iron can claim purity in the technical sense of the word. Pure iron combines considerable tensile strength up to 40 kilogrammes per square millimetre (56,900 lbs. per square inch), with such toughness that rods of a finger's thickness can be forged cold into knots like hempen cord. Its melting temperature lies high up in the region of white heat.

Nearly all chemical elements can, in smaller or greater quantities, be formed into homogeneous compounds with iron, thereby totally changing its mechanical characteristics. With some elements a few thousandth-parts suffice to change iron into a metal which, although the colour remains unaltered, really differs more from pure iron than does copper from bronze. Strange to say, the usual companions of iron are not metals, but other elements. Among these, carbon takes the most prominent place. Carbon receives first consideration in all metallurgy of iron, and determines the general character of all iron alloys. At all steel works the name of "carbon" is so constantly pronounced that one might suppose iron to be without any separate importance. By taking up carbon, all tough iron undergoes changes as essential as they are technically important. While the percentage of carbon rises from zero to one per cent., the tenacity of iron increases in strict proportion from 40 to 100, elongation and toughness decreasing at the same time from 40 to 6. The natural hardness of the metal perceptibly increases. The most important fact is this: carbon is the real steel producer; for to that alloy it imparts the faculty of obtaining, by sudden cooling, an artificial hardness. Everything made of steel contains carbon: a file and a machine tool, about one per cent.; the blade of a knife, about one-half per cent.; a rail, about one-quarter per cent. Every different use of the metal demands a different percentage of carbon, which has been determined by experience as being best suited to the purpose.

If the carbon increases beyond one per cent., the tenacity of the iron decreases, and the alloy, even in its natural state, is brittle, and therefore useless.

Iron, when molten, has a very strong affinity for carbon, and if brought into contact at once assimilates it. But, even in its solid state, rods of iron, if packed with powder of charcoal in stone troughs and heated to a dark red, will change into steel. The natural consequence of this affinity is, that iron, when reduced from the ore in the blast furnace, takes from the coke an average of four per cent. of carbon. This is unavoidable, and forces the metallurgist to a further process in order to remove the carbon and to obtain soft malleable iron. Thus the production of iron consists of two separate operations; making raw or pig-iron from the ores, and changing pig-iron into soft iron. The many efforts made to obtain iron free of carbon from the ores direct have, so far, always demonstrated

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PUDDLED STEEL ROLLING MILL

that it could not be done as economically as in the ordinary roundabout way.

Although carbon is prominent among the companions of iron, there is, besides, quite a multitude of different elements which complicate the variety of alloys and the detail of metallurgical processes, so that modern metallurgy is a science as profound and difficult as it is wide. Let us mention first silicon, the chief component of quartz, clay, and many other minerals which comprise the surface of the earth. This non-metal is a constituent received by molten carbonated iron from the slag of the blast furnace, from the fireproof bricks and the crucibles; while its immediate influence upon the qualities is not great, and certainly not especially detrimental, yet it plays an important part in the production of forgeable iron; and to it, also, we owe the useful kind of pig-iron known as cast-iron. For, about 2 per cent. of silicon in pig-iron causes the molten metal, during its solidification, to discard part of its carbon in the form of graphite, distributed through the whole mass, and so to free itself from a hardening and brittle-making influence. Pig-iron, poor in silicon, called white pig-iron, is too brittle for use, and is only important as an intermediate product used in the manufacture of wrought-iron. A third ever-present companion of all irons is manganese, and certain ores, viz., the spathic ores from the valley of the Sieg, in Germany, contain such quantities of it, that, in the blast-furnace, they make an alloy of more than 10 per cent. of manganese, called "Spiegeleisen" or "spiegel;" by melting this with peroxide of manganese, so-called ferro-manganese is obtained, which often contains more manganese than iron. Manganese, like silicon, especially displays its influence in the production of wrought-iron, or of steel. It acts on the properties of steel in the same way as does carbon, but only about one-fifth as strongly.

These three elements, and with them, for certain specialities in steel, additions of tungsten, chromium, nickel, and other metals, are improving or neutral elements, from which alloys of iron of marvellous strength and virtue may be composed. On the other hand, sulphur and phosphorus must be counted foremost among detrimental poisons in iron. The mischief caused by sulphur is that it makes iron and steel break under the hammer when at red heat, prevents their being forged or rolled, and so creates difficulties, although only for the manufacturer. But phosphorus causes such "shortness" that a bar, containing a few thousandth-parts of it breaks to pieces when dropped on the pavement. A cutting tool, if containing only one-thousandth of phosphorus, would at once lose its sharp edge. So, in the best steel, not more than a few ten-thousandth-parts of it are allowed. Unfortunately, it is an ever-present companion of iron ; some ores contain several per cent., which goes entirely into the pig-iron by the blast-furnace process, only very few highly valued mines furnish an iron with less than one-thousandth phosphorus. The elimination of it in making soft iron has only very recently been successfully accomplished by the basic open-hearth process. By this the phosphorus is not entirely removed, but only a very small proportion remains, which for most purposes is harmless.

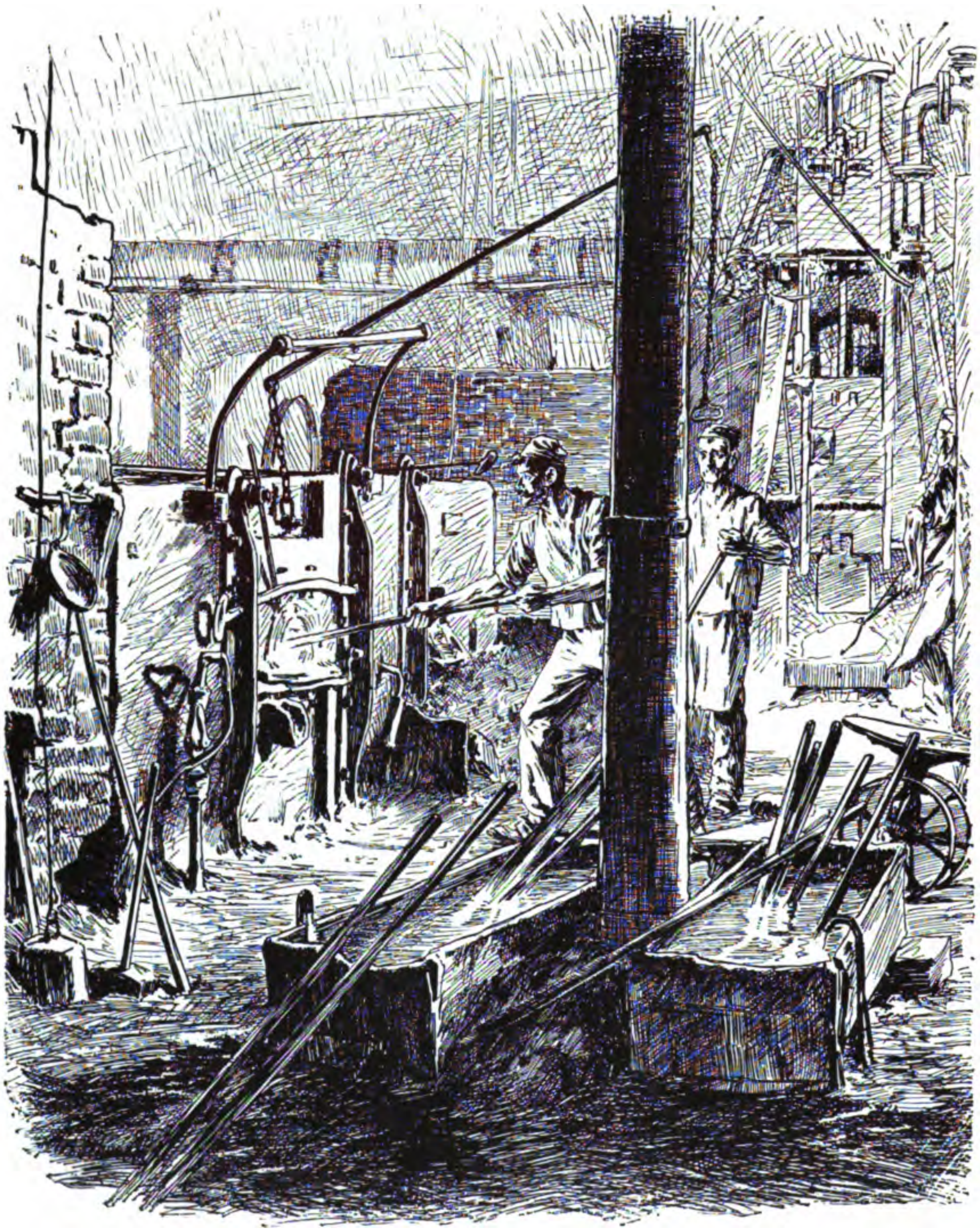
The description of the inner qualities and mechanical properties of steel may here be concluded. Wishing not to abuse his readers' patience, the writer has limited it to what he deemed necessary. Whilst passing through the different departments of the factory, we shall find opportunities for adding a few details. Modern metallurgy has turned its back on the empiricism of bygone days, and carries on its work scientifically, according to the rules of chemistry and molecular physics. We can now scarcely realise the difficulties of the inventors of cast-steel, Huntsman and Friedrich Krupp, whom none could tell how much carbon or phosphorus was contained in their steel, and who had no conception of the parts played by silicon or manganese. Nowadays, the manager of a steel factory would, without the aid of chemistry, be like a helmsman without a compass ; so that even small steel works have their own laboratories and scientifically trained chemists. Of the dimensions, the apparatus, and the capacity of Krupp's laboratories, it is difficult for an outsider to form an idea. For such objects as the improvement or acceleration of their working no expense is spared. The writer has always entered these halls with a certain envy, and just a little feeling of sadness, for they make him realise with what miserable means, at how great a sacrifice of time and energy, he himself, and many other scientists, have been obliged to pursue their scientific investigations of metallurgical problems.

MAN WITH BLOOM-TROLLEY

CHAPTER VII

STEEL AND IRON PUDDLING

PREPARED by some information, we begin our walk through Krupp's Works at Essen in order to observe in actual practice all those things which we have just reviewed mentally. Our next stopping-place lies far off in the southern part of the grounds. We cross the public road at gate No. 1, or, as they say in Essen, at "Portier 1." The ground on the other side of it rises gradually to the level of the government railroad, so that the railroad tracks which run from here to the lower part of the works are, when they reach there, on a level with the roofs. Walking up, and turning to the right, we enter the puddling works. Three high airy buildings, each one 70 metres by 40, lying close together side by side, form one large workshop, in which the old and picturesque labour of "stretching" the iron is practised on a large scale. At all hours of the day and the night the traveller may here enjoy looking upon a scene of active life and may admire the magic effects of light. Half-nude and sooty fellows, with hooks and rods, are busy at the furnaces, illumined by the brilliant rays of the metal which glows within. Now and then, flaming lumps of iron are pulled through the open furnace doors, put on small two-wheeled carts, and drawn to one of the steam-hammers. The ram gently descends, pressing out the slag, which runs down red hot from the anvil. Gradually a square block is



PUDDLING FURNACE AND HAMMER

formed, the force of the blows increases, and the slag in glowing patches strikes the screens. The so-formed "blooms" are, by means of long tongs, at once drawn to rollers. The rollers seize them, and quickly pass them to and fro through smaller and smaller openings, which, by a sequence of grooves, are left between the upper and lower rollers. Afterwards there may be seen three or four rods like fiery serpents shooting forth from different points of a train of rollers. And then, besides this, the whirring fly-wheels, the oscillating levers of the steam-engines, the men hurrying hither and thither, all unite to form a picture which, particularly at night, when phantastically illumined by ever-changing rays of white and red, is well fitted to inspire even such a master of art as Menzel, and to furnish him with subjects for some of his famous pictures.

As soon as our eyes and ears become somewhat accustomed to their surroundings, we approach one of the furnaces, from which the last shapeless mass of iron, with the slag flowing copiously from it, has just been drawn. When the door is raised we see a hearth spanned by a low vaulted roof, under which roll flames entering from a great fire fed with coal, and at the other end emerging by a flue, where the hot gas on its way to the chimney yields a portion of its heat to a tubular boiler. It is evident that in such a furnace the iron is kept from contact with carbon or ashes, and is subjected to the oxidising action of the air, of which an abundance flows in with the flames.

The lining of this furnace, where wrought-iron is produced, is not made of ordinary fireproof material, but, in order to take up phosphorus, is composed of water-cooled pieces of cast-iron, covered with a thick layer of iron slag and scales, which in the furnace itself is melted on to the hearth. Before the furnace receives a new charge the fire is damped, and by carefully injecting water the hearth is somewhat cooled off. Then a few shovels of scales are spread equally over the hearth; and when these have been followed by 260 kilogrammes (570 lbs.) of pig-iron, the door is closed, the chimney-valve opened, and the fire worked to its greatest heat.

On examining the pig-iron which is used here, we find a fracture of white colour with a tendency to crystallise in needles. This tells us that it contains, in addition to its carbon, only a small quantity of silicon, and about two per cent. of manganese. Such pig-iron is received at the puddling works from Krupp's blast-furnaces near the Rhine, where it is made from certain mixtures of ores, its quality being invariably the same.

Half an hour must pass before the charge is melted; so in the meantime we turn to another furnace where the melting process has just been completed. At this stage most of the silicon and manganese is burnt, and together with much oxide of iron has passed into the slag. The low degree of oxidation of the two metals imparts the remarkable faculty of taking free oxygen from the furnace gas and of transferring it to the carbon in the molten pig-iron. Therefore it becomes the main task of two workmen constantly to stir the mass, in accordance with certain rules, to "puddle" it, in order to bring the slag which transfers the oxygen, into close contact with all parts of the charge. Very soon we see bubbles of inflammable carbonic oxide gas emanating from it, a sure sign that the decarbonisation has begun. This reaction increases, and in a few moments the bath is boiling, part of the slag running over the front rim of the hearth. Gradually the boiling quiets; the metal, after losing most of its carbon, becomes less liquid, and at last changes into a doughy substance. Then begins the hardest task of the puddler. The whole mass must be kneaded with rod and hook and divided into six equal parts (in metallurgic language called "blooms") which are for some time rolled to and fro, in order thoroughly to expose them to the oxidising action of the flames. About two hours after charging the furnace the blooms are ready, having now assumed the form of large sponges of pig-iron filled with slag, and preserving but slight traces of the elements which as pig-iron they contained. At least four-fifths of, if not all, the phosphorus has gone into the slag.

We have already seen how the blooms are hammered and rolled into rough and irregular bars of the width of a hand and the thickness of a thumb. A machine breaks off both ends of each bar. These bars are sorted on a shelf, and by the appearance of their fracture furnish the foremen and managing engineers a means of regulating the proper quality of the day's production.

These first coarse bars are made into commercial iron, by cutting them in short pieces, binding them together in piles, heating them in furnaces to white heat, and then rolling them into bars, rails or plates. This is done in various other departments of Krupp's factory, but solely for its own requirements.

STEEL AND IRON PUDDLING

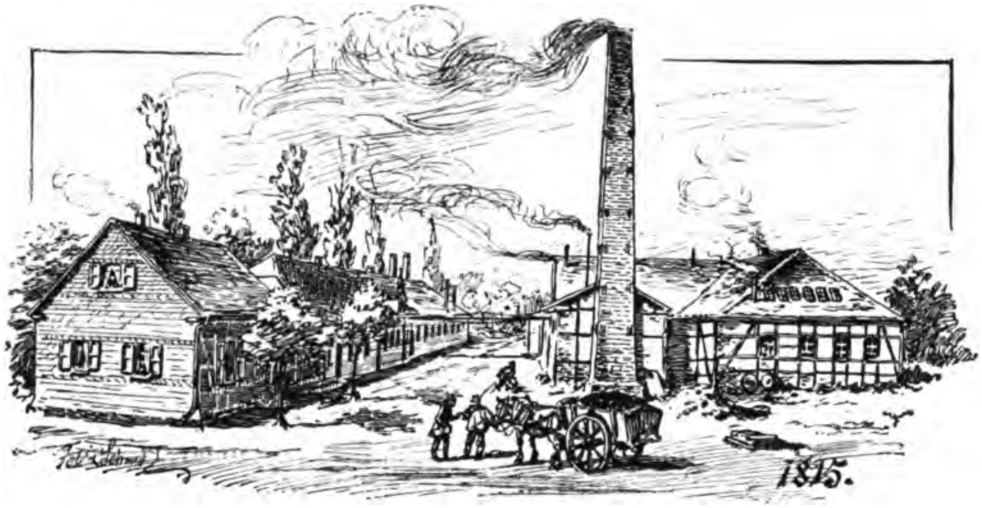
The above described process, in its present shape more than a hundred years old, has developed from the ancient refining forge. It seems imperfect and antiquated, for it requires much manual work, and the quality of the product depends in a high degree upon the skill and conscientiousness of the puddlers. Also the process is slow and yields but little, two furnaces worked by five men producing only 6000 kilogrammes (13,000 lbs.) a day. But, in spite of all predictions to the contrary, puddling still occupies an important place in iron metallurgy, the smith preferring its product for the reason that iron generated in a doughy form will weld better and more easily than any other kind. Besides, the fibrous, interlaced texture consequent upon this mode of making iron, offers a sure guarantee against any sudden breaking from internal strain.

It is scarcely worth while to remark that it is not necessary to go to Essen in order to see wrought-iron made. At the same time, Krupp's puddling works, with their sixty-five furnaces and eight trains of rollers driven by eight engines, are in size and convenient arrangement probably unequalled. They also rank first as to the excellence of the raw material used and as to the purity and even quality of the product. It is a rule in the works that even ordinary construction iron must not contain more than a thousandth-part of phosphorus. However, it is not the production of wrought-iron, which makes Krupp's puddling works specially interesting, but a variation of the process; namely, the production of steel by puddling. This is done in the same furnaces, with the same appliances, and by the same workmen. The pig-iron, too, is of the same character as that used in puddling iron; but its mean percentage of phosphorus must always be less than 0·1 per cent. As to the work itself, only the eye of an expert would distinguish a slight difference.

The mode of reheating the steel blooms is as unusual as it is rational. They are not, as in other factories, put into special reheating furnaces, but are replaced in the puddling furnaces from which they were taken while the pigs for the next charge are disposed about the border of the hearth. The steel blooms, returning red hot from the hammers, are put on the hearth, and well covered with slag; then the fire is started as usual; half an hour later the blooms are taken from the furnace. They have the proper heat for the finishing rollers, and at the same time the pigs for the next charge have been melted.

After every three charges most of the slag is removed through a special aperture, in order to prevent its contents of phosphorus and sulphur from increasing beyond 0·3 per cent. The furnace yields twelve times daily 250 kilogrammes (550 lbs.) of steel, from a charge of 270 kilogrammes (594 lbs.) of pig. In iron puddling the output is 260 kilogrammes (572 lbs.) fourteen times a day.

The bars of steel obtained are sorted separately for every furnace. Then about a finger's length of their ends is struck off, and expert workmen divide the day's work into three classes, guided by the appearance of the fractures. Class A contains 0·9 to 0·75 per cent of carbon; class B, 0·75 to 0·65; class C, under 0·6. Work is paid by the weight of these bars, but the price for Class A is considerably higher than for Class B. Steel of Class C is refused.

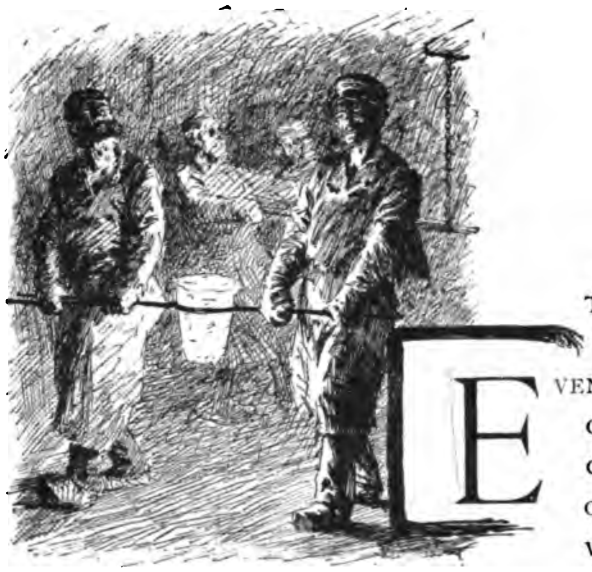


KRUPP'S STEEL WORKS IN 1815

Puddling for steel demands great skill, attention and exertion. The chief difficulty lies in the interruption of the decarbonisation at the right moment. However, Krupp's foremen and workmen are so skilful and experienced, and have, by the system of payment, been taught to be so careful, that Class C appears but very rarely on the labour records.

In its chemical composition the steel obtained in this way is of the very finest quality. Excepting its carbon and 0·2 per cent. of manganese, it shows but slight traces of foreign elements; in particular, of phosphorus and of sulphur, it shows respectively maximums of not over 0·03 and 0·01 per cent. The real averages are only half these quantities. Therefore this material certainly equals at least the Danemora iron from which Sheffield in Britain makes its best steel.

Nearly the whole output of puddled steel remains at Krupp's works, not for immediate use, but as raw material for the manufacture of cast-steel. In the steel foundry, ~~where we shall go next~~, it is cast into ingots for cannon. Krupp's cannon factory is the chief consumer of the puddled steel. Of course its managers put the highest conditions on the quality of this material, and the strictness shown by them is more dreaded in the metallurgical department than that of any outside customer. The business management of all the great departments is on a similar basis, and has a most wholesome effect on all of them. Alfred Krupp's dictum that "*in my factory second-rate material will not be used, and shall not be made,*" has become a law, and is the rule for the organisation of the whole establishment, including blast-furnaces and iron mines.

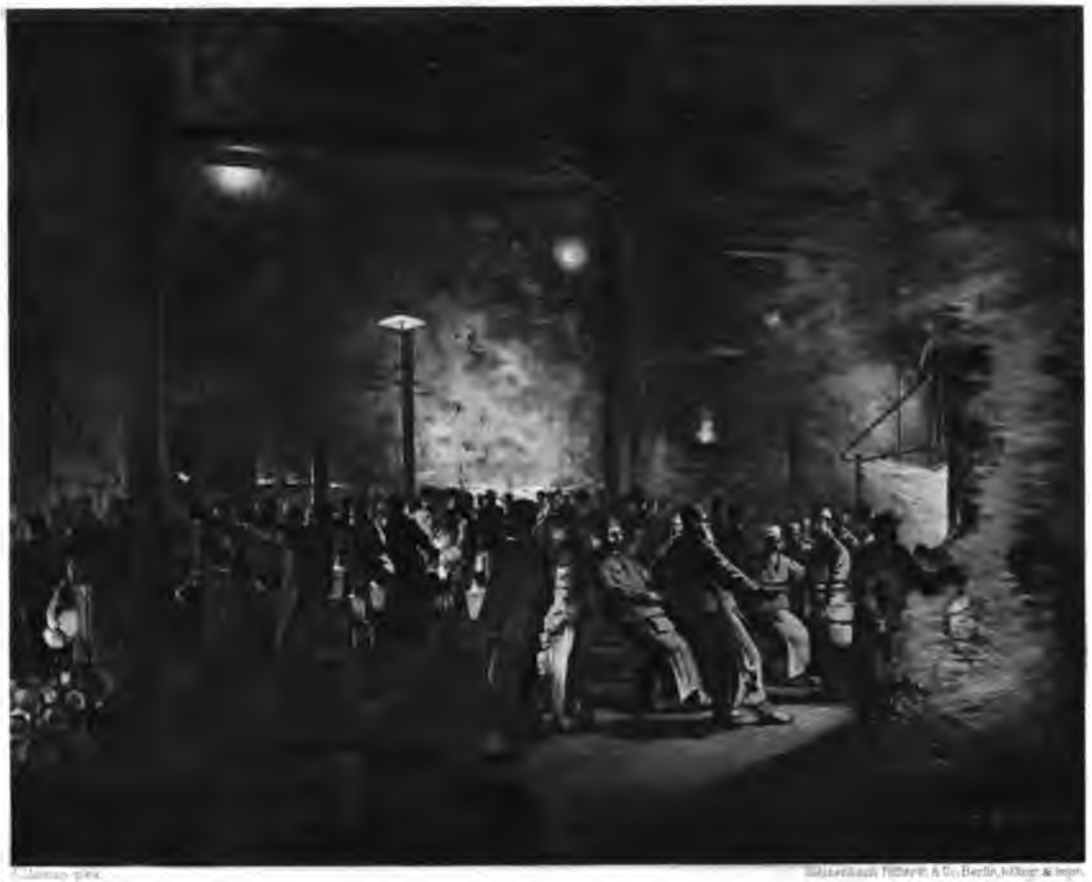


CRUCIBLE CARRIERS

CHAPTER VIII

THE CAST-STEEL FOUNDRY

EVEN if the chemical composition of steel or wrought-iron produced in the puddling furnaces, or on the refining forge, is the very best, one extremely important physical quality is always lacking: viz., homogeneity. The metal cannot in the first place be perfectly homogeneous in consequence of the way it originated from a doughy mass in which fibres of varying hardness were kneaded and welded together. This condition is well demonstrated by etching a polished surface, and thus developing the well-known damask figures. And, worse than this, there is a remnant of slag, which in microscopic particles pervades the whole material. It seems evident that the slag cannot be quite driven out from the steel impregnated with it, by hammering or by rolling; which is also the reason why puddled steel and wrought-iron will not take a high-grade polish. In tools this lack of uniformity causes the cutting edge to nick and to become quickly blunted. In very small objects, such as watch-springs, even the minutest particle of slag is ruinous. Therefore, quite naturally, it was a watchmaker, Huntsman of Sheffield, who energetically undertook to solve the problem of making homogeneous steel on a manufacturing scale. He began the practical execution of what seemed to be a plausible idea. This was to melt puddled steel in chemically indifferent vessels under exclusion



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CASTING CRUCIBLE STEEL.

of the air, keeping it liquid for some time, so that every trace of slag must rise to the surface, and the metal must necessarily become absolutely uniform. By dint of persistence he succeeded, in 1770, in making, out of a certain fireproof clay, suitable crucibles, and in them correctly carried out this kind of melting. Before long a number of his townsmen gained possession of his secret; and at the beginning of this century Sheffield, at a high price, provided the world with the famous English cast-steel, and with steel tools of such fine quality that every one then believed them to be unsurpassable. It is well known that to this day the family and successors of Huntsman, as well as a number of other good Sheffield firms, still work in this old method. It is one which has long since ceased to be a secret, and the writer was allowed to make important studies in two of those factories—namely, those of Seebohm and Diekstahl, and Jonas and Colver. Bars of the best Danemora wrought-iron are converted into steel by annealing them for several days in powdered charcoal; then they are sorted according to their percentage of carbon, broken into small pieces, and melted in clay crucibles, after which they are cast into small ingots in cast-iron moulds. These ingots are forged or rolled into smooth bars, which are sold as tool steel of the best quality. Heavy castings and forgings for construction iron are not made of superior crucible steel either in Sheffield or elsewhere in England.

Simple as the melting of cast-steel appears at the first glance, it yet offers a number of unexpected technical difficulties, which can only be successfully met by empirical means, and to this fact is due the secrecy which surrounds the manufacture of cast-steel. One difficulty is in the making of the crucibles. Not all fireproof clays are suitable, as the crucibles, from great shrinkage after drying and heating, are liable to crack. Even if most of the clay, after first being burnt, is ground to powder again, and to bind it, mixed with fresh clay before being moulded into crucibles, these must be dried very slowly, indeed often for months. And even then it still remains very questionable whether the crucible will stand the very sudden changes of temperature which occur in melting and casting, or if it will endure the pressure of liquid metal. Nature has, for the Englishman, much facilitated the manufacture of cast-steel by giving him the clay deposits found near Stourbridge and Stannington. The crucibles made of these clays, in rather a primitive way, and with an addition of a very little powdered coke, are ready for use after the comparatively short time of five weeks, and will then stand the most severe usage. Other clays, and more especially the German clays, can rarely be used in their natural state, but must be made more fireproof, and less sensitive to changes of temperature, by a considerable addition of certain kinds of graphite.

A second difficulty is the tendency of steel to take up hydrogen and nitrogen, which, whilst solidifying, it evolves in the form of bubbles. This will make a steel quite useless for tools and for most other purposes. Only after many failures and much experience were the rules established which must be followed in order to make sure that the castings from crucibles will be homogeneous and free from blow-holes. At the same time it was learned that crucibles of different composition, which had been differently treated, would act on the steel differently, and that Sheffield methods were not always applicable in Continental steel-works. Only recently has scientific research thrown some light on these dark problems. It has been found that by the natural action of the wall of the crucible on molten steel part of the silicon is reduced, and so all cast-steel contains about one-quarter per cent. of silicon. On the other hand, it has been proved that a small addition of silicon prevents the release of the occluded gases. This binding of the gases does not, of course, occur if the steel is cast as soon as melted, but in order to take up silicon it must remain one or two hours longer in the furnace at a high degree of heat. In this way the beneficial effect of what the English call "killing" finds its scientific explanation.

On the Continent the manufacture of cast-steel was not seriously attempted until 1811, when the Continental embargo prevented its importation from England. But one man only was successful, and was rewarded for his exertions and sacrifices, namely, Friedrich Krupp of Essen, the grandfather of the present owner of the factory. He was the second inventor of cast-steel; his methods were his own secret; a mere imitation of the English mode of manufacture, even had it been known to him, is, by what has been said above, shown to have been out of the question. As early as 1815 he began to compete with the English in making a number of commercial articles of cast-steel. In 1818 he built a new factory near Essen, which was the nucleus of the present works. It had eight furnaces for one crucible each. Every furnace produced two daily castings of twenty-five pounds, the weight of the ingots not exceeding forty pounds. The crucibles he made of a certain mixture of Rhenish clays with a considerable addition of graphite. His raw steel was made by cementation of Siegeländer irons. According to an estimate of the "Verein zur Beförderung des Gewerbfleisses in den königl. preussischen Staaten" (Union for the encouragement of industrial efforts in the Royal Prussian States) for the year 1822, the product of Friedrich Krupp's factory was judged to be equal in usefulness and quality to the best English steel, and to be in some respects even preferable to it.

But, in spite of its propitious inauguration, through the illness of its owner and some external mishaps, the prosperity of the factory so declined that at the time of Friedrich Krupp's death in 1826, his son Alfred, then only fourteen years of age, found himself with a scanty force of workmen standing by the wreck of his heritage. During the next fifteen years the factory only earned enough to pay the workmen their wages. It was only after 1841 that Alfred Krupp's invention of the spoon roller furnished him with the means for enlarging his factory. Absolutely convinced of the superiority of his steel, he endeavoured to find new fields for its use. In 1847 he made the first cannon of cast-steel, and at the same period he began to make his raw material in the puddling furnace. In 1851 he exhibited in London a cannon, a six-pounder, made entirely of cast-steel, and also a solid flawless ingot of steel weighing 2000 pounds. Then, with one stride, the Essen factory took first place among all the steel factories of the world. Soon afterwards it furnished not only tools but heavy shafts and long shaft rods of superior cast-steel. In 1853 Krupp's famous invention of cast-steel railway tyres, made without welding, proved to be of great importance with regard to the development of the works; the profit derived from this he used partly for the enlargement and equipment of his factory and partly for the practical execution of his favourite scheme, namely, making a breech-loading cannon of cast-steel. The whole world knows how at last his inventive genius, his persistence and his hard work won their well-deserved success.

The present crucible steel foundry is an immense hall of 200 metres by 80, resembling in its architecture an old Roman basilica. The wide and lofty middle aisle, flanked by iron columns, has in the centre a casting-canal four metres wide, and with this exception and that of three travelling cranes, of which the high trestles span the canal, this aisle is nearly empty, as are also the adjoining halves of the side aisles. The wide floor has on either side nine large melting-furnaces, and behind each one of them there stands at right angles a heating-oven for the crucibles. The melting-furnaces are built according to Siemens's regenerative principle, the hearth being placed at about half the height of a man above the floor. Such furnaces are heated by generator gas which, at Essen, comes through subterranean flues from a gas-plant of sixty-eight generators. The gas, as well as the air required for its combustion, is brought to a temperature of 1000° Centigrade in subterranean heaters before entering the furnace proper. This excellent firing system, by which Friedrich Siemens once led pyrotechnics into new paths, makes it possible to increase the furnace heat up to any desired limit.

The crucibles are put in and are taken out of the furnaces through two doors by means of long tongs with counter-weights hanging from rollers. This part of the work is quick and easy, the men standing so far off that they are not much affected by the great heat radiating from the furnace.

We enter this foundry at about four o'clock in the afternoon; the whole wide space seems practically deserted. The furnaces are charged and a few workmen are busy preparing the mould in the middle of the casting-ditch for an ingot block of fifty tons. The mould is the shape of a hollow truncated cone, it has thick walls of cast-iron, and weighs but little less than the ingot itself. It has been put, wide end downwards, resting on a thick iron plate, into the casting-ditch. Now above the mould they cover the pit with iron plates, leaving only two openings. Then they set up two long casting-troughs, leading, with a moderate incline from both ends of the building, to the centre of the pit.

As the casting will not take place until 5 P.M., let us in the meantime inspect the workshops auxiliary to the foundry. We pass between the furnaces to the rooms where they charge the crucibles. We are first attracted to a place from whence proceeds a continuous rattling and crackling. Raw steel, as made in the puddling works, is here deposited in large heaps. Several cars loaded with it have just arrived on a narrow-gauge railway track. The brittle rods of steel are taken from the cars and are fed into a machine, where in quick rotation they are broken into short pieces by grooved rollers. The pieces fly about and are collected by shovels. They form the raw material for Krupp's cast-steel, and are very uniform in their composition; that composition must vary according to the intended quality of cast-steel, and by adding certain ingredients special steels are produced which differ from the normal article. In works like these, probably everything in this direction which is practicable, as well as much which has proved impracticable, has been tried.

The required proportions of every charge are weighed. A special brigade of workmen skilfully put the pieces into the crucibles, others put covers on the crucibles and cement the joints with clay. Each cover has two holes of an inch wide, one in the centre, the other near the edge. The latter serves its purpose when the liquid steel is poured out, the former makes it possible to observe, when desired, the progress of the melting.

The charged crucible must make a journey through the air by means of a complicated system of rails and rollers. It is seized by tongs, suspended on a roller, pulled to the end of a rail, and carried over to the tongs of the next man. The circuitous journey ends before the door of the heating-furnace in the foundry. The melter, who waits there for it, puts it into its chamber in the furnace.

CLEANING THE CRUCIBLE FROM SAND

After having seen the crucibles charged and transferred to the furnaces, let us visit the crucible-room. As the success of the casting chiefly depends upon the quality of the crucibles, great care and attention are bestowed on their manufacture. The mixture of which they are made is prepared from several kinds of clay with a considerable addition of graphite, and worked by men and machinery into a condition of perfect uniformity, then put in a press, from which it issues in the shape of a thick cylinder, open at either end. This is cut by hand into pieces of equal length, one for every crucible, then the weight of each piece is taken and, if necessary, corrected. Then the pieces are pressed by a wooden rammer into a steel moulding-flask, which shapes them on the outside. A conical piston, guided absolutely vertically, is then pressed down in the centre, just deep enough to force the clay to fill the flask to the border which closes it above. After the double flask is opened, the moist crucible (resting on an iron plate, put under it before beginning the pressing process) is lifted into an elevator and transferred to the drying-rooms.

Whilst we are looking for an exit from the labyrinth of the crucible works, the signal is given from the foundry that the casting is to commence. We hurry there, and we are confronted by a spectacle which would surprise and fascinate even the *blasé* audience of a great theatre. On this vast stage swarm hundreds of muffled men, reminding one of ants on a disturbed hill. Amongst them, as if soaring above the ground, move the glowing crucibles, shedding a red glare on the figures and faces of the men who carry them. And, in contrast, sunbright rays stream from the open furnace doors, over the busy groups below to the girders of the roof above. We soon distinguish that the crowd consists of four currents of men, which, beginning at the farthest furnaces in each corner of the hall, increase as they pass the nearer ones, and slowly approach the casting-pit. Each crucible is held by double-handled tongs, and carried by two men. These groups, approaching the casting-trough from both sides, pour into it the white, glowing, liquid steel through the side hole in the cover of the crucible. After emptying it, which is done in a few seconds, they at once make room for other groups and, passing down the middle of the aisle, emerge from the crowd, rid themselves of the empty crucible, and return to the furnace to repeat their circuit. When a heavy block is being cast, every group of workmen must carry ten crucibles to the trough. At the furnace we find men busy with the big tongs, putting one crucible after another on the edge. Two men stationed beside them seize the crucible with ordinary hanging-tongs and, with one pull, draw it to that corner of the furnace where the foremost group of men stands ready to receive it and to carry it away.

Within half an hour twelve hundred crucibles, containing fifty tons of steel, are emptied in regular order. Even a layman must understand that such work can only be achieved by means of the utmost skill and a strict discipline enforced by most intelligent managers who have benefited by many years of practical experience. The whole complicated human apparatus works with the precision of a machine. But yet mechanical training has not destroyed the individuality of these men. They move freely, and neither their gait nor their attitudes show any military stiffness. No loud commands or expostulations from captain or officers are heard. This little army works almost noiselessly at an eighth wonder of the world.

Before the big block of steel solidifies, one or two hours must elapse. It is sure not to contain even the most minute blow-hole, and to be throughout of the chemical composition which was beforehand determined upon. It is the latter condition especially which renders casting from crucibles superior to any of the more modern and cheaper methods of steel production which are described in the following chapters. And this is the reason why, for his cannon, Krupp uses exclusively crucible steel. He has no intention of giving up the practice, although in all other steel-manufacturing countries Martin (open-hearth) steel is used for this purpose. In manufacturing and in using ingots of crucible steel, weighing up to the astonishing amount of eighty-five tons, Krupp's factory stands alone. There are in other parts of the world large steel works, gigantic steam-hammers, and gunworks, but no other puddling works or crucible steel foundry which equals in capacity those of the Essen steel factory.

MOULDERS

CHAPTER IX

THE SIEMENS-MARTIN PROCESS

Although the crucible process is invaluable for the manufacture of first quality steel of distinct chemical composition, it is comparatively very expensive. Therefore, on account of an immense increase in the requirements of railroads and steamships, it became necessary, in order to replace puddled wrought-iron by the so evidently superior cast-steel, to find cheaper modes of manufacturing the latter. The problem has been solved in two quite different ways. Because of its relation to the puddling and the crucible method, we will first turn our attention to the open-hearth process.

The old idea of melting the steel not in crucibles but on the open hearth of a furnace, thus making the furnace play the part of hundreds of crucibles, came near being realised when Friedrich Siemens invented firing by gas, and successfully introduced it into the manufacture of steel in the place of coke fires. With his assistance the French engineer Martin, in 1863, succeeded in putting the idea into actual practice.

In comparing the hollow of a Siemens hearth to a large crucible, the purely physical view of the matter is taken. The essential difference between the two is this: the hearth cannot, like a crucible, be closed by a cover, and consequently the chemical influence of the oxygen in the burning gas has the same effect that it has in the puddling-furnace. Thus the carbon especially is attacked during and after the melting. Therefore good raw steel does not produce on the hearth cast-steel of equal hardness. But pig-iron can be added to the charge, so that after melting it contains a certain excess of carbon, and the desired grade of hardness can then be attained by continued heating. Besides which, the decarbonisation of a bath of many tons—as the slag transfers oxygen to its surface only—is so slow, that barely 0·1 per cent. of carbon disappears in an hour, so that it is possible, by taking tests from the bath and by observing the time, to watch the progress of this action, and to let the metal out of the furnace at the right moment. Moreover, no harm is done by carrying the decarbonisation a little too far, as shortly before casting the metal can be recarbonised by adding pig-iron. In practice it is done in that way, a pig-iron rich in manganese and silicon being selected for recarbonising, because experience has proved that these elements prevent the formation of blow-holes.

In case a great excess of carbon is to be dealt with, an addition of oxidised iron in the form of iron-glance or red hematite ores will hasten the process. Not only does the oxygen they contain bind an adequate quantity of carbon, but the pure iron after reduction also dilutes the bath and increases the output. Of course pig-iron also can, in this way and without any addition, be made into cast-steel, but the process is altogether too slow, therefore in practice the tendency is to use as little pig-iron as possible.

From what precedes, it is evident that, with regard to the results obtained, the Martin process is almost as sure as the crucible process, while in flexibility it is superior. For a crucible, after being charged, can only produce one distinct kind of steel, while the Martin open-hearth process, by means of carbonisation and decarbonisation, will produce steel of all grades.

Also the open-hearth process works almost automatically, and does not necessitate the use of either machine power or of especially skilled labour. It supplies, together with the Bessemer process, a large part of the ordinary steel suitable to the demands of railways and machine shops. This process also fills an economically important part insomuch as it permits the use of all scrap-iron, defective and worn-out pieces of wrought-iron. One class alone of this, namely, all the rails and tyres which must every year be replaced, furnishes an immense amount of raw material which is in great demand for open-hearth work. Formerly, all such scrap was taken to the blast-furnace, made again into pig-iron, and the entire labour of changing it into a forgeable state had to be repeated.

Since 1880, the important invention by Thomas and Gilchrist of the "basic" hearth has developed some changes in the Martin process, and has greatly added to its importance. In order to understand why this is so, let us examine the construction of the hearth. The furnace, as a whole, differs but little in principle and in construction from the Siemens furnace as seen in Krupp's cast-steel foundry. But the hearth is hollowed out like a bath tub and slopes a little towards the back, where an outlet, which is closed during the melting, is placed. This part of the furnace coming, as it does, into direct contact with the molten metal and the slag, must not only be fireproof but also very resistant to chemical attack. A lining of slag similar to that in a puddling furnace cannot be used; its place is taken by powdered quartz, combined with just enough clay to hold it together. This mixture covers the hearth to the depth of half a yard, resting on a foundation of cast-iron plates supported on pillars. Before work begins the lining of the hearth is baked in the furnace itself at high heat.

This lining, satisfactory in every other respect, has, because of its acidity, the very undesirable effect of preventing the separation of any phosphorus from the bath. Consequently, even in the manufacture of ordinary market steel for construction purposes, the charges must not contain over 0·1 per cent. of it; and no superior steel can be made of scrap-iron, because that contains an average of over 0·05 per cent. of phosphorus.

These limitations disappeared after the discovery that a resistant basic lining could be made of strongly burnt dolomite and tar, which would combine with silicic and phosphoric acids; thus making it possible to extract the phosphorus from the bath.

When the basic open-hearth process is properly managed, the percentage of phosphorus in its product can be reduced below the limit of that contained in the best Danemora iron.

On account of these advantages, the basic Martin process has been everywhere accepted, and is beginning to supplant the acid process; all the more so, for the reason that it can be carried out with quite as great, if not with superior, ease and cheapness. The selection of the raw material is only limited in so far as to contain as little sulphur as possible; for, contrary to

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CASTING OPEN HEARTH STEEL

all expectation, this element is not eliminated from the metal by the basic hearth. As to recarbonisation and the addition of gas-binding material, the same rules hold good for the basic as for the acid hearth.

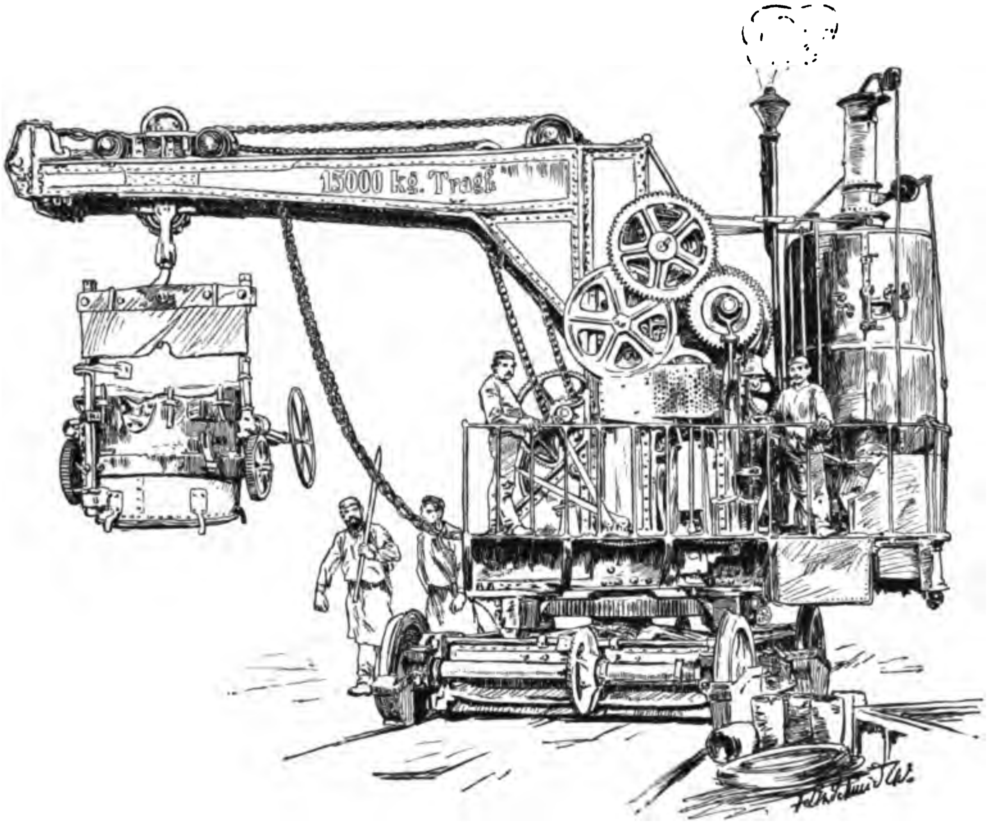
Krupp's factory has no less than four large Martin plants. We will go and visit Martin Works No. 1, built in the beginning of 1871, and producing 80,000 tons per year.

It was the first works of this kind built on a large scale, and even to-day remains among the most important, a monument to the foresight and the enterprise of Alfred Krupp. Its hall of three aisles, sixty metres by forty (196 feet by 131), the wide casting-pit in the middle, and the lines, on both sides, of five furnaces each, make it look like a smaller edition of the crucible steel foundry. But here the backs of the furnaces reach the line of the columns, and they are fed from the two side aisles. The rim of each hearth rises about half a metre above the floor. The furnaces, with the exception of the short spout of the outlet, are closed at the back. Each one has under the outlet a special slag-pit, completely separated from the main pit.

The entire contents of a furnace are emptied into the great ladle, an iron vessel of immense size, lined with fireproof material, and having an outlet in the bottom capable of being opened and shut at will by a stopper.

By means of travelling cranes, the ladles can be put under the spout of the furnaces, filled with liquid steel, and transported over any one of the moulds put up in the main pit. Each of the four cranes rests on a low travelling platform bridging the pit. They are in themselves mechanical marvels of imposing size and capacity; their turning-post, which is furnished with a long arm, reaches to a considerable height, thus allowing the ladle hanging from the chain to be lifted several yards above the floor and to be lowered an equal distance into the pit. On their platforms are carried complete steam-engines and boilers, by the power of which the engineer can lift or lower the ladle, or any other object weighing up to seventeen tons, or he can turn it in a circle to the right or to the left, and carry it forward or backward through the entire length of the hall.

The foreman takes us in front of one of the furnaces and pulls up the middle door. We are blinded at first as if we gazed at the sun, but, after protecting our eyes by a dark green glass, can see the flames rolling through the interior and the boiling fluid on the hearth, where the bursting bubbles emit small flames of oxide of carbon. What we see of the bath is not the metal, but a covering of slag several centimetres thick, by which intermediary oxygen is transmitted to the metal. The process has advanced to the second stage of decarbonisation, and the melters are just adding some hundredweights of ore in pieces the size of a man's fist. These sink under the slag and betray the immediate reaction of the bath by a great seething.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CRANE OF FIFTEEN TONS CAPACITY IN MARTIN STEEL WORKS, No. III

We approach another furnace which is nearly fit to be emptied. A sample of metal has just been taken out by a long-handled ladle and put into a small iron vessel. It solidifies quickly, is cooled by water and broken; by the appearance of the fracture the expert foreman discerns that the bath still contains a little too much carbon. Half an hour later another test shows the desired result. Then follows the addition previously mentioned, of pig-iron rich in silicon and manganese, and a few minutes later the signal for casting is given. The scene at once becomes animated. Its engine puffing, its chains rattling, the crane approaches and swings the big ladle over the square pit behind the furnace. The ladle, red hot inside, descends, and is put under the spout of the outlet. Some of the workmen have taken off most of the clay with which this outlet was cemented, and only a stopper remains to be removed. Against it is pressed a heavy suspended iron bar, and a few blows from a hammer on this bar drive the stopper inside. A dazzling jet of metal, as thick as a man's arm, shoots forth, and in a few moments the ladle is filled. The ladle is instantly removed, and the slag allowed to flow into the pit. Then, with the ladle suspended, the crane moves off to the flasks for which this charge is destined. Eight ingots of one ton each are cast in open cast-iron moulds, and the solidification takes place as quietly as with crucible steel.

Returning to the furnace we find its three doors open, and the heating gas turned off. The edge of the hearth has suffered some erosion; its injuries are repaired by plastering them with hearth material, which is put on with a long-handled trowel, pressed down and smoothed over. After this operation the outlet is again cemented. At both ends of the furnace chamber we see, side by side, the fire apertures which admit gas and air. The vault above the hearth, in accordance with the older system, slopes down towards the centre, so that the flames may be pressed down upon the bath. After the hearth is repaired, in order to bake the new part of the lining, the furnace must once be fired at maximum heat without a charge. Then a new charge is put in, of which, in this Martin works, pig-iron usually constitutes over one-third. When the pig-iron is melted, several portions of scrap steel are added. Worked in the manner we have described, each furnace making four charges, their daily production is about thirty or forty tons.

Martin workshop No. 1 chiefly produces superior steel of medium hardness in billets of all sizes, suitable for springs, tyres, projectiles, axles, and other forgings. The scraps from the crucible steel factory furnish it with a raw material which as to purity fulfils the highest requirements. This workshop is also much used for the production of steel castings. The moulding is done in an adjoining building. When we enter this building, we first see several bright spacious rooms, where by means of wooden models and moulding machines of different sizes, the moulds of moist clay are made. Wheels and crossings for railways, toothed wheels and rollers, are the chief products of this department.

At the first glance, the work here appears to be done in exactly the same way as in an ordinary iron foundry; but there is an enormous difference. While with cast-iron and many other alloys the cheapest and most convenient way of making complicated and irregularly shaped objects is by casting them, this art, in its application to steel, on account of the high temperature and great shrinkage of the metal, becomes much more difficult. The material for the moulds must be fireproof, and also somewhat yielding, otherwise the object cast—say, for instance, a wheel—would crack in shrinking. It was not until 1851 that steel castings were successfully made. This was first done in Germany, at Bochum and at Essen. They are now, in more or less perfection, very generally produced. Every maker claims the composition of the moulding material he uses as his own special secret. It generally consists of the powdered *débris* of fireproof bricks or broken crucibles, with the addition of sufficient clay to make it plastic when moist, and hard and coherent after burning. After the moulds are shaped, they are dried in large chambers, like gigantic baker's ovens, which are heated by generator gas. The moulds are gradually heated until they turn a dark red. In two or three days the moulds are hard and fit for use.

The casting is done in the Martin workshop. It is hardly necessary to say that whatever the origin of the metal used for this purpose may be—whether it comes from crucible, open-hearth furnace, or Bessemer converter—it is absolutely essential that it should be entirely free from blowholes.

One speciality of the Krupp works is the production of very large and complicated castings of low grade, tough steel, so-called homogeneous iron (Flusseisen), suitable to the demands of shipbuilders for stems, rudders, propellers, &c.

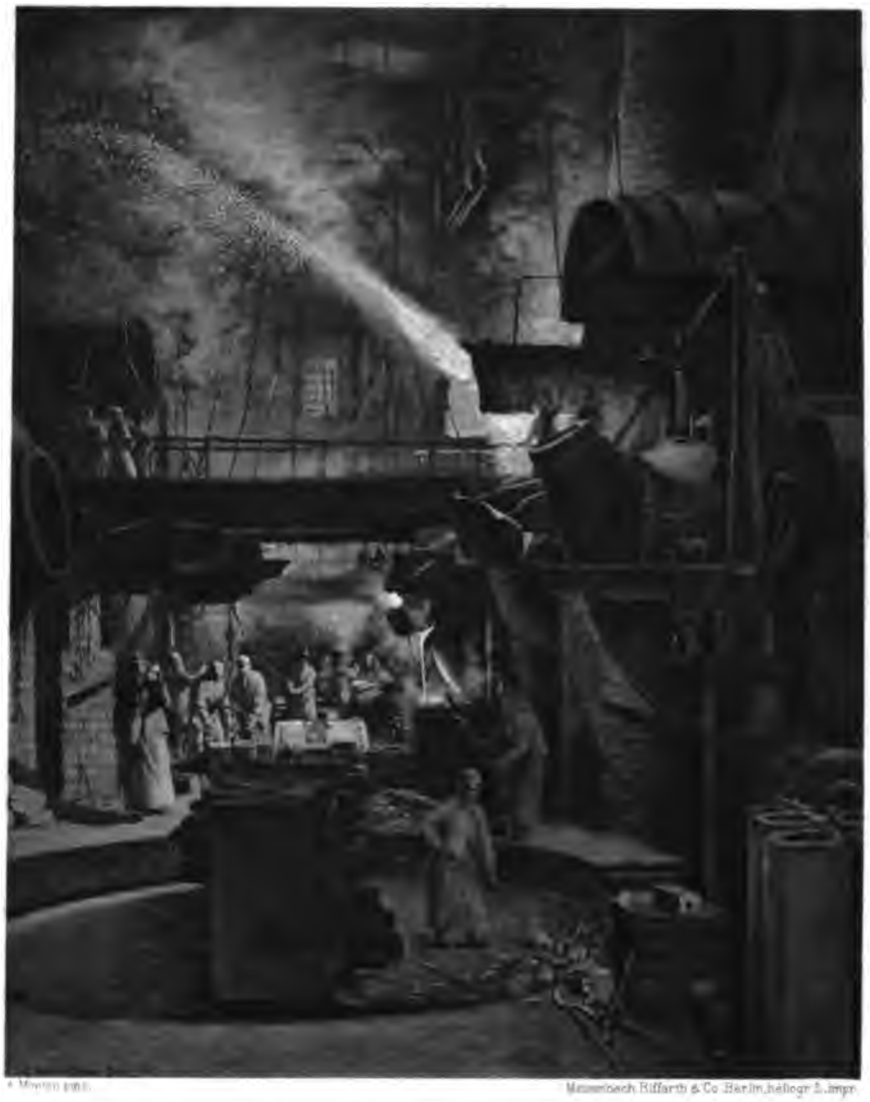
When it issues from the broken mould, a casting is still far from finished. First the gates are cut off by slow working circular saws. These gates, where the metal enters, must, in proportion to the size of the piece cast, be very long and wide, or otherwise the hollow funnel caused by shrinkage would reach down into the casting. Then follows the necessary and important operation of annealing. The pieces, carefully supported to prevent them from bending, are placed in large ovens, and by a smoky flame slowly heated to a red glow. After being for several days kept in this condition, they are finally left to cool off in the same ovens. If the metal is correctly selected, and all known precautions are observed, castings treated in this manner nearly equal in tenacity and toughness forged pieces of the same grade of hardness. And after being cleaned they delight the eye of a connoisseur by the smoothness and regularity of their surfaces, the sharp outline of their edges, and their general perfection of detail.

Martin Works No. II., which we reach after a short walk, is a fine new plant, similar in its general arrangement to No. I. It is, however, somewhat wider, more space being given where the furnaces are charged. At present it only contains five large basic-lined furnaces of fifteen tons capacity. The travelling cranes have a capacity of twenty tons, and are in design similar to those we have just inspected. The hearths are paved with a mixture of dolomite and tar, and are isolated by a layer of magnesia bricks from the rest of the masonry, which is made of fireproof bricks. The vault above, in accordance with modern ideas, is concave, so that the flames pass through the furnace following the middle plane, and the charge receives their heat entirely through reflection and radiation.

The basic process, which closely resembles the other, requires repeated additions of unslaked lime. The average percentage of phosphorus in the charge is here two to three per thousand: it unites easily with the slag, so that nothing containing more than 0·03 per cent. of phosphorus in the charge is allowed to pass; while, as a rule, the proportion is less than half of this amount. The output is chiefly restricted to low steel and homogeneous iron, for wire, plates, and other articles made by rolling. The very lowest "flusseisen," which only contains slight traces of carbon, and which is used to make boiler plates, has the tensile strength of the best wrought-iron, and is not inferior to it in welding capacity.

The third Martin plant lies in the lower part of the factory near the crucible steel foundry. It has two large furnaces, and serves almost exclusively for the production of steel castings. The newest Martin plant, No. IV., is in the south-east corner of the press building: this we will later see in action, in connection with the manufacture of armour-plates. Without question it is as yet unequalled in the domain of the Martin process.

Emulating the spirit of old Krupp, the makers did not linger, cautiously feeling their way to the further development of a metallurgical invention which was recognised as being efficient; they at once translated it into gigantic proportions with that bold courage which only the full consciousness of power can inspire. Until then a Martin furnace of fifteen tons capacity, such as we have just seen, was considered a large one, and a capacity of twenty-five tons the maximum. The two basic open-hearth furnaces in Krupp's Martin plant No. IV. both master in one day two charges of forty-five tons each. The two ladles are each large enough to receive this quantity of metal at one time. Two travelling cranes of seventy-five tons capacity lift and carry them with ease to the moulds. A quarter of an hour suffices to cast an ingot of eighty tons. And this gigantic task is quietly accomplished in a corner of the building by but a handful of workmen.



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BESSEMER CONVERTERS

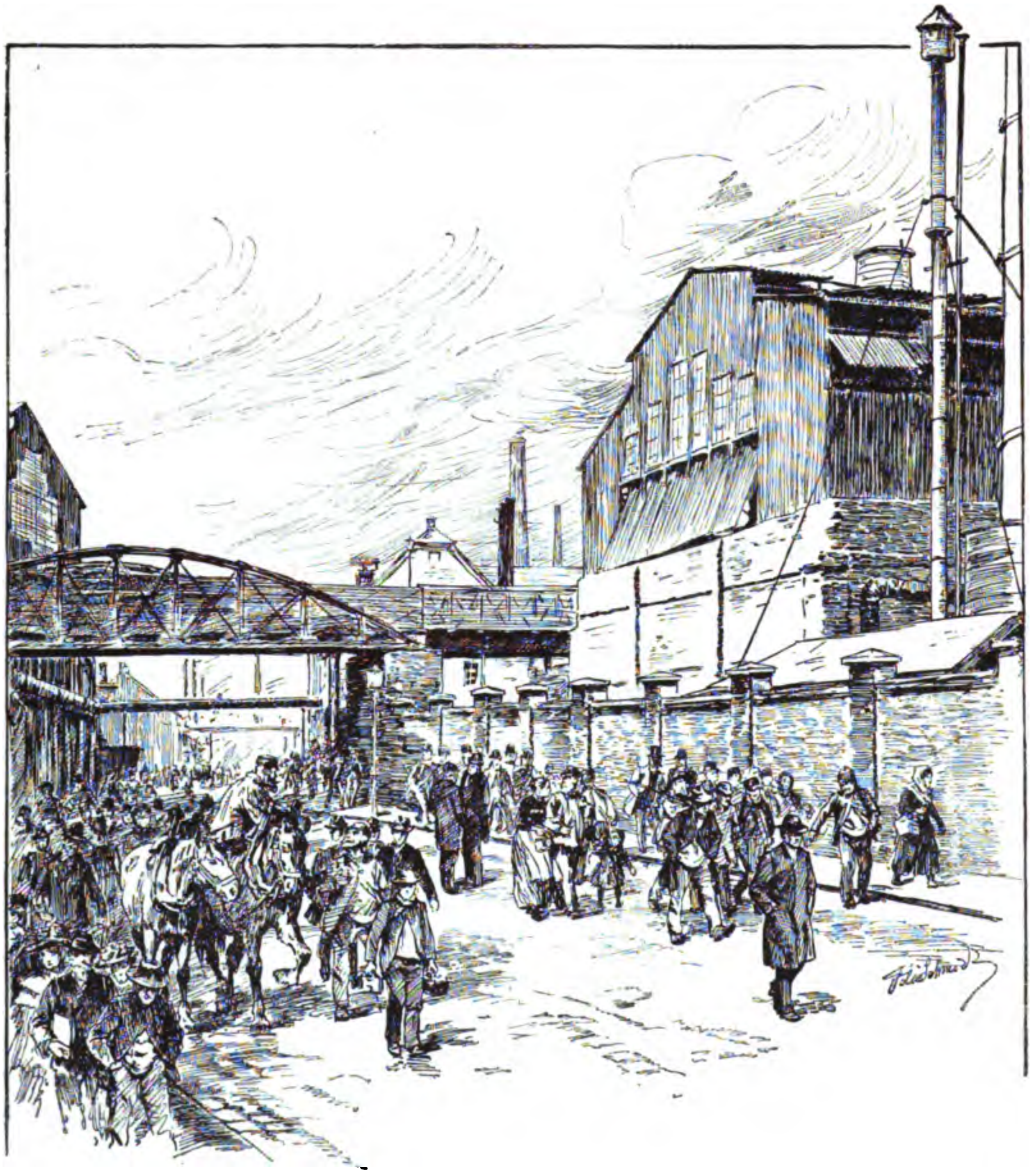
CHAPTER X

THE BESSEMER PROCESS

WHILST in the puddling and in the Martin process oxygen only reaches the molten metal from the surface, and slowly penetrates the mass through the medium of the slag, according to the Bessemer process many thin currents of air are, under strong pressure from below, forced through a column of molten pig-iron. The foaming mass, by this means separated into atoms, comes into such intimate contact with the air that all oxygen is rapidly absorbed. Consequently, the oxidation of the foreign elements present in the pig-iron keeps pace with the quantity of air received. Ten tons of pig-iron contain about 200 kilogrammes (440 lbs.) of silicon, 350 kilogrammes (770 lbs.) of carbon, 200 kilogrammes (440 lbs.) of manganese, which for their combustion require 760 kilogrammes (1670 lbs.) of oxygen, that is to say, 4000 cubic metres (5000 cubic yards) of air. If the blowers are sufficiently powerful to force through this quantity of air in ten minutes, a cartload of iron can in that short time be produced.

It is of great economic importance that in this operation the foreign elements eliminated, especially silicon, act themselves as combustibles, and raise the temperature of the bath far beyond the melting point of wrought-iron. By a proper addition of pig-iron the metal may be recarbonised, drawn into a collecting ladle, and, in the manner we have already described, cast into ingots.

The chief appurtenance for carrying out the process sketched above is a large cylindrical vessel of heavy boiler plate, lined a foot thick with fireproof material. Its bottom, which is pierced by several hundred air-holes



LIMBECK ROAD DURING DINNER HOUR

of one inch in diameter, can easily be taken out and exchanged ; the upper part is a cap with an opening on one side. This pear-shaped vessel can by trunnions and a wheel and pinion be turned round a horizontal axis into any position. The trunnions are hollow, and from the pipes outside the air flows through them, first into an air-chamber and then into the converter. By means of this arrangement air can be blown inside not only in every position the converter takes, but also while it is turned. The pig-iron which is to be treated is melted in a cupola furnace, then by a trough introduced into the trunk of the converter, which has been lowered for the purpose. Then the air pipe is opened and the converter is raised. About twelve minutes later, when the process is completed, the converter is turned horizontal, and slowly inclined, so as to pour the liquid steel into the ladle below.

The Bessemer process, which has been known for thirty years, has now conquered the world, and its influence on the economical conditions of the different countries has been keenly felt. But early in the sixties its practical use met with such difficulties that it was only kept up in two small plants at Sheffield, which were not flourishing. While the attitude of the great majority of steel producers was hostile to it, Alfred Krupp, on the contrary, at once recognising the practicability and great possibilities of the invention, resolved to establish a Bessemer plant on a large scale.

The first charge in the Essen factory was blown on May 16th, 1862. The plant then consisted of four converters of two and a half tons, and four others of five tons each. Two years later a second plant, comprising six converters of five tons, was built. Then the first plant was altered and furnished with nine converters of five tons. It is very remarkable that at a period when, for the rest of the world, the Bessemer process was still in its infancy, Krupp, for an annual production of 130,000 tons, should have built and worked these plants, which still remain among the most extensive of their kind. This fact, which is not generally known, is a brilliant confirmation of the traces of his remarkable genius which we meet with at every step in the Essen factory.

In the Bessemer process, owing to the superb and varied effects of fire and light, the rapid progress of the work, the number of interesting machines used, and the intelligently ordered union of so many different powers, there is more to fascinate a visitor than can be found in any other metallurgical process. The first impression is particularly overpowering, when, as in Krupp's Bessemer plant No. 1, three groups of converters in the same hall are all seen simultaneously in action. From a little distance the whole building appears to be filled with fire. From every door and window stream vivid rays of light, piercing their way through the murky atmosphere; red smoke and fire rise from the chimneys. Without entering the works at all one may enjoy the spectacle from the Limbeck Road, which closely approaches the Bessemer buildings. In the illustration, "Limbeck Road during dinner hour," the factory is seen on the right; over the bridge which spans the road the pig-iron is carried to the platform of the cupola furnace.

When we first enter the Bessemer works the light blinds us, and some moments must elapse before the noise and stir of all the different operations cease entirely to bewilder us. In the converter on our right the process of decarbonisation is going on, and a roaring greenish white flame, several metres long, shoots forth from its trunk and buries itself in the chimney above. Further back another converter has just been turned upward, and emits an immense volume of smoke and sparks which spread all through the workshop. From a third converter on the left, the white glowing steel flows into a ladle until the slag runs over the brim. In the nearer founding pit the ingots from the last casting, still hot, form a crimson circle. By means of a hydraulic crane some workmen are busied in lifting them upon a train of small cars, which a quiet percheron horse then drags off into the darkness under the left hand gallery.

In a few moments the picture changes. The flame shooting from the first converter sinks, then disappears, while in its place there flows from the opening a thick white smoke which as it rises changes to red. The liquid iron has parted with all its carbon, and at a signal from the foreman the converter is turned down. A gutter is pushed into its trunk, by which, in order to restore to the bath the desired percentage of carbon, a certain quantity of pig-iron is introduced.

In order to mix it thoroughly the converter is two or three times moved up and down, which operation always projects a characteristic and gigantic sheaf of sparks, rising even to the roof. In the meantime the converter on the left has been prepared to receive a fresh charge. The end of a system of gutters, suspended on iron rods, is already connected with its orifice, and a man on the platform to our right is occupied in forcing the stopper from the outlet of the corresponding cupola. A fiery stream of molten pig-iron shoots down in little cascades, smoking and shedding vivid sparks, until it disappears into the belly of the monster.

Now that our nerves are steadied and our eyes and ears have become inured to their surroundings, let us try to examine more closely the general plan and arrangement of the works. The building is a lofty one, eighty metres (262 feet) deep, and is divided into three aisles. On either side of the middle aisle, which is nineteen metres (59 feet) wide, are four converters facing each other, each one raised four metres (13 feet) above the floor; while yet another converter stands on the side of the southern gable. In the side aisles behind the converters and on a level with them runs a platform ten metres (33 feet) wide. On the right side the platform is supported by very solid masonry, and on it rise in line the great shafts of six cupolas, of which the fore hearths are constructed according to Krigar's system. A second platform from which these cupolas are charged runs above the other. The before-mentioned narrow-gauge railway, which carries the pig-iron and coke, terminates here. Behind each converter there stands on the platform a smaller cupola in which the iron for re-carbonising is melted.

For working, three converters together with two cupolas form a group. In every group, whilst one converter is in action another is being repaired, and the third is kept in reserve.

Between all the opposite groups of converters, and in front of the ninth one at the end of the building, there is a circular casting-pit, having in the centre a hydraulic crane, which carries a ladle at the end of its horizontal arm. Eight hydraulic lifts, placed near the pits, serve to raise the flasks and to transport the ingots.

The tipping of the converter is not done in the usual way by the aid of a hydraulic machine, but by small steam-engines, one of which is stationed by the side of each converter.

All the converters are lined with quartz material, therefore they do not withdraw phosphorus, of which, in consequence, the pig-iron must contain less than 0·1 per cent. Owning large mines of the purest iron ore, the firm is able to produce in the blast furnaces near Duisburg and Neuwied, an ample supply of excellent Bessemer iron of uniform quality. Therefore there has not, as yet, been any occasion for considering the introduction of the basic Bessemer process.

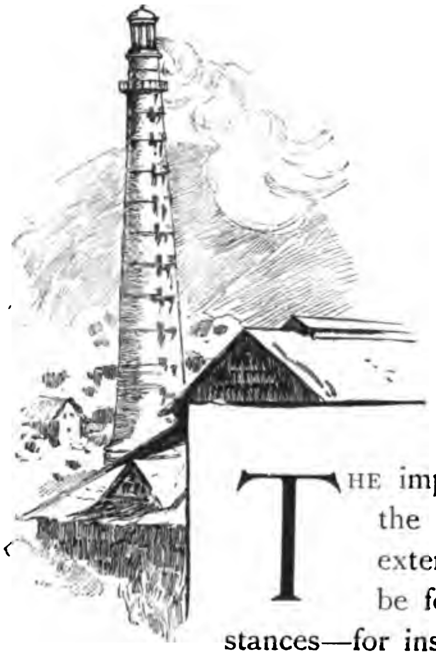
Krupp's Bessemer works at present make billets weighing up to 1000 kilogrammes, used almost exclusively for rails. The pig-iron which has an average of 1·5 per cent. of silicon and 2 per cent. of manganese is melted down with a great deal of coke, so that it reaches the converter considerably over-heated and makes hot charges. The bath is not decarbonised to the limit, and the recarbonisation is not done with spiegel, but with white pig-iron rich in manganese. The steel whilst being cast and during solidification is perfectly quiet, showing no seething or foam. Thanks to the excellence of its raw material and to an experience gained by thirty years of practice, this Bessemer plant works with the perfect uniformity of a machine. During the last ten years the writer has seen it a number of times and has always found the quality of its raw material, its proceedings, and the character of its product, unchanged.

The machines auxiliary to the Bessemer process are also very interesting. In the engine-room of the adjoining building we first meet with the pumps for the hydraulic cranes, then with seven noisy Root blowers furnishing the blasts for the cupolas; and finally with one upright and three large horizontal air compressors of 500 h.p. each; all four of them being servants of the converters. A third air-compressor in the building on the other side of the road is the largest in the world, and is in itself a sight. It is upright and is divided into three storeys, its total height being fourteen metres (46 feet). The diameter of its steam cylinders is 1·24 metres (48·82 inches), while that of the compressing cylinder is 1·57 metres (55·8 inches). The stroke is 1·73 metres (68·10 inches); and the indicated power 2000 h.p. This engine, which usually drives the Bessemer plant (the others being kept in reserve), is able to furnish the blast to five charges simultaneously.

The ingots cast in the Bessemer shops, whilst still hot, are carried on small cars drawn by horses into the preparatory rolling-mill immediately adjoining the left side of the building. By means of an ingenious arrangement of tongs and levers, they are without delay inserted in Bicheroux heating furnaces, and are gradually approached to the flames. These furnaces require very little fuel, as they are not so much intended to heat the ingot as to allow its already acquired interior heat to spread equally through it. They may consequently be considered as substitutes for the so-called soaking-pits, which do this part of the work in other factories. After the ingots have throughout assumed an even temperature, they are rolled, on one of the two trains of the blooming-mill, to about half their original thickness. Two heavy steam-hammers do what forging is required, and a large shears divides the ingots into smaller pieces, and also cuts off their ends. After this first rolling, the ingots intended for rails are sent to the rail rolling-mill, and although this is 2700 metres (nearly 3000 yards) away, the ingots reach there still red hot.

The two triple roller trains, set up in 1877, are capitally equipped. They are driven by Corliss steam-engines of 550 h.p., and, managed by very few men, work almost automatically, and as economically as the latest kind of American rolling-mills.

Here we bid farewell to this great and time-honoured Bessemer plant. Without having made much noise in the world, it has had a large share in the growth of Krupp's factory, and it has produced enough steel to encircle the globe with a continuous railroad track.



CHAPTER XI

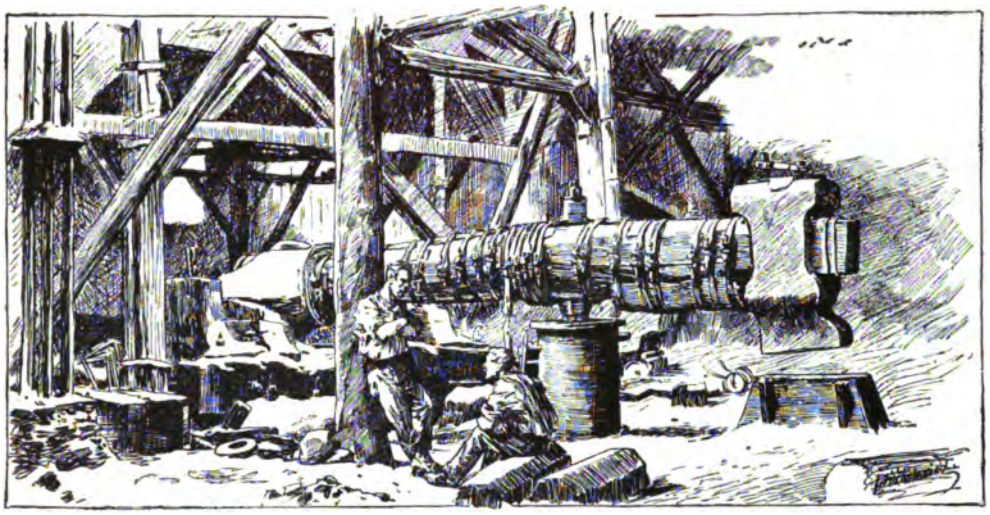
THE STEAM-HAMMERS

THE important part which metals have played in the development of civilisation is to a great extent due to the ease with which they can be forced into any shape. Whilst other substances—for instance, wood and stone—can only be given certain forms by dividing them, and by removing small portions, metals, on the contrary, can be either cast or forged. To forge a piece of metal is to subject it to a series of mechanical pressures which oblige it to change its shape in accordance with the will of the forger. Iron especially, and also its alloys known as steel, become at high temperature so plastic that forging is the most natural as well as the best method of shaping them.

In comparison with forged pieces, steel castings, in spite of the immense progress which has of late years been made in the art of manufacturing them, must still take a secondary place. Moreover, it is not alone his solicitude as to shape which renders a steel manufacturer unwilling, for instance, to make a long shaft by casting. He prefers to stretch it out of a short ingot, by hammering or pressing, because experience has taught him that thorough forging refines the texture and improves the quality of the metal. Although it is possible that in the future steel castings may be produced of a quality which equals that of forged material, still under present conditions, forging is, whenever possible, preferred to casting.

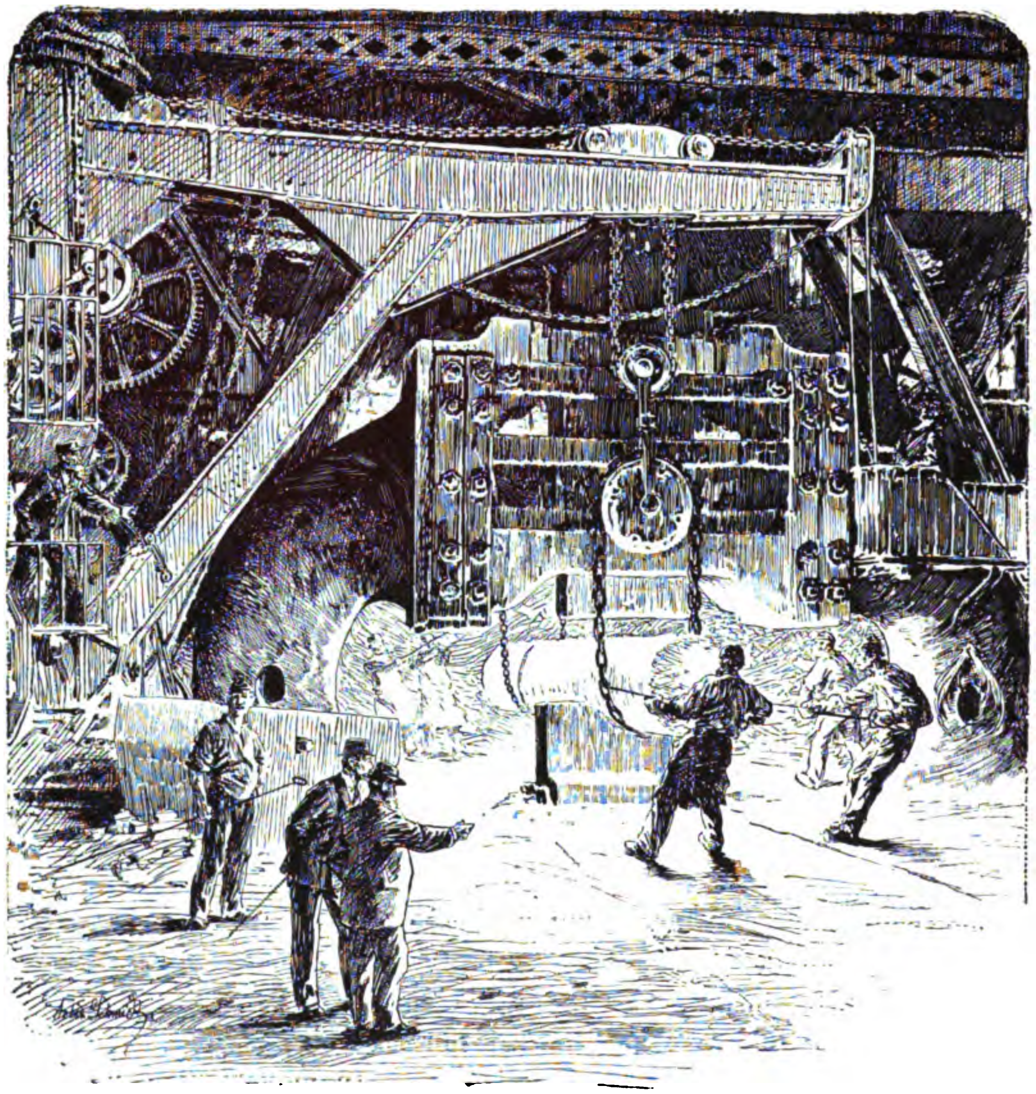
THE STEAM-HAMMERS

Among all tools used for forging, the oldest, the most important, and those which can be used with most variety, are the hammer and the anvil. For centuries past, by means of these simple implements, real marvels have been produced. But ancient forged irons consist of artistic pieces of small dimensions easily wrought by hand. The development of modern machinery, of railroads, and of steamships, has exacted heavier pieces for the fabrication of which the heaviest hammer that can be swung by human hands is quite inadequate. At first mechanical hammers were used of the same shape as hand hammers, but having a tree's trunk for a handle, and weighing hundreds of pounds. In countries where coal is scarce and water plentiful—as, for instance, in Sweden or Styria—many such hammers are still employed. Real steam-hammers only began to be gradually introduced into the iron shops early in the forties. In movement as well as in appearance they are totally unlike hand hammers; bearing, in fact, more resemblance to pile-drivers.



OLD-FASHIONED HAMMER

The most important part of a steam-hammer is a cast-iron ram, which being guided vertically, is raised by steam-power, and is brought down again by its own weight. The ram is suspended from the piston-rod of a steam cylinder, which is supported by an **A**-shaped frame. The cylinder connects with a valve operated by a lever. When this lever is raised,



HAMMER, "FRITZ"

steam is admitted into the cylinder from below, and forces up the piston, which lifts the ram; pressing the lever into its lowest position cuts off the steam, and connects the lower entrance with the escape, so that the ram falls without hindrance.

Steam-hammers constructed on this principle took their place towards the middle of this century, in all the larger iron and steel works. But then a ram of ten tons was considered to be of maximum weight. And without doubt a hammer a thousand times as heavy as the largest ever swung by the arms of a smith is a formidable tool. But it proved by far too weak when Alfred Krupp commenced to forge his heavy ingots of crucible steel into axles, shaft rods, and cannon. With his usual energy, he at once resolved to build a giant hammer, which in the field of large forging tools should eclipse everything then existing. Everywhere he went, his idea pursued him; he thought continually about the constructive principles of the hammer, and often got up at night to note down improvements which occurred to him, keeping for this purpose a big pencil and a drawing-block always at hand. At the time, his plan seemed so adventurous that experts even declared it to be an outcome of insanity.

On September 16, 1861, the famous hammer was first tried. Foremen and workmen had awaited the day with anxiety, and when for the first time the heavy ram slowly ascended, to come down with tremendous power on the gigantic cast-iron anvil block, all those standing near instinctively jumped backwards. Krupp alone did not flinch. He had from the beginning felt sure of success. The erection of this hammer (involving an expenditure of 1,800,000 marks—£90,000) was a remarkable exploit, which unveiled new horizons to the whole technology. All large hammers built later were modelled after this one, which for a long time remained the largest in the world. Krupp christened his beloved iron child "Fritz," and under the motto "*Fritz sei fleissig*" ("Fritz, keep busy") the giant hammer has now for thirty-three years worked untiringly, ever assisting the growth and adding to the fame of the Essen works.

"Fritz" and his younger brother "Max" stand in a separate building 110 metres in length by 60 metres in width (360 feet by 196). Through a lofty arched portal, adorned by an inscription in memory of a visit made by Emperor William I., we enter, and suddenly find ourselves before the giant. Unfortunately the shop is rather dark, and the dimensions of the hammer are not clearly visible; for at the time it was constructed the traditional idea that a blacksmith's shop ought to be half dark still existed.

Let us take advantage of the hammer's being idle to examine it more closely, for only in that way can we appreciate its size. As we step under the large frame and stand close to the ram, we observe that this is double the average height of a man, and that even if laid flat on the ground it would reach as high as a man's chest. The operator goes to the lever to show us that this huge tool can be managed by him as if it were a small hammer held by a skilled smith. He presses the lever and the ram flies up three metres; then a pressure in the other direction and the enormous mass, representing six carloads of iron, comes hissing down. It seems as if the anvil must be crushed to atoms! But no, at the last moment, the operator turns on steam, and the ram, just before touching the anvil, remains for a moment suspended, and then rapidly ascends again. This operation is repeated a number of times, forging, so to say, in space. A walnut is then placed on the anvil, and the hammer cracks the shell, leaving the kernel intact.

But the hammer itself forms only a part of the whole installation, also including the anvil which receives the shock, and the basis which diffuses it; the latter, on account of the galleries of old mines, which hollow the ground beneath, being necessarily of unusual dimensions. It consists of a pyramid of pig-iron, as high as a house, and weighing not less than one million and a half kilogrammes, and is itself supported by an independent foundation. On its upper part is a groove; in this is fastened the anvil, which can easily be changed. Anvils of different shapes, suiting the work to be done, are used. Thus, one for round pieces is shaped above like a **V**. The basis can also be fitted with a mandrel jutting out sidewise, upon which hoops are forged.

Two revolving cranes of fifty tons, and two of thirty tons capacity, one couple of which are placed in front of, and the other couple behind the hammer, serve to bring on, and to move, the pieces to be forged. Each one is provided with a steam-engine, furnishing the power to turn its arm of ten metres length in any direction, thus enabling the said arm to move the charges either horizontally or vertically.

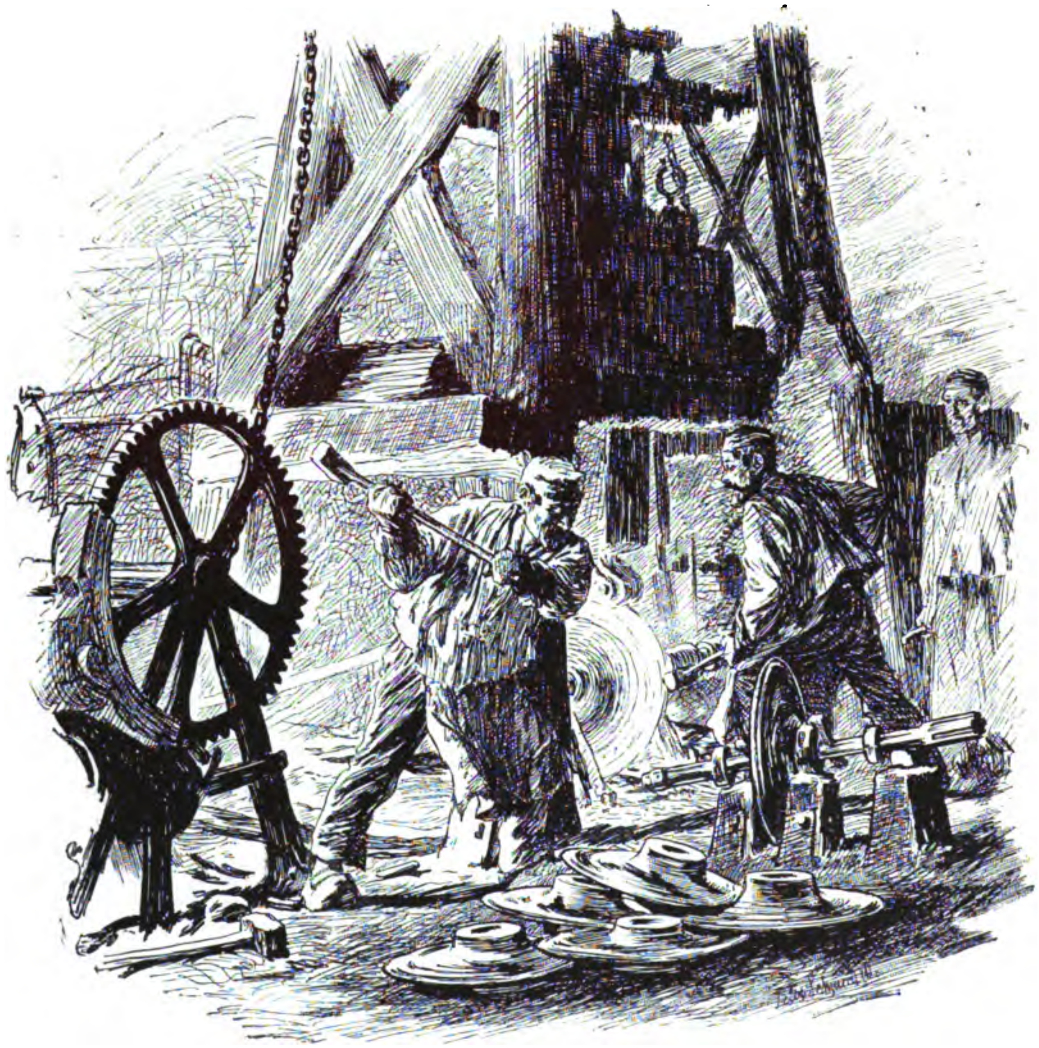
Finally, the installation is completed by four large reverberating furnaces, serving to reheat the pieces to be forged. They are placed laterally, and in such a manner as to be accessible to the arms of the cranes. In all of them the chamber, while narrow, is six metres long, and the hearth rests on wheels. They are simply heated by coal burned on a grate which is placed in the chamber.

But work is about to begin. A block of crucible steel, weighing 40,000 kilogrammes (40 tons), which is to be forged into a cylinder 10 metres long, destined to become the **A**-tube of a ship's gun, has attained the proper temperature. The furnace door opens, and the yellow-hot block emerges on the movable hearth. The nearest crane is put into motion. With admirable skill the workmen place the chains exactly at the block's centre of gravity, so that, by means of long steel bars, they are able to maintain its equilibrium, and to guide it to the anvil. Then blow follows blow. In spite of their force, the rumbling noise is not very loud, and the concussion of the earth is almost imperceptible. But from the roof above, the puffing of the escaping steam distinctly reaches our ears. On account of the great resistance of steel, even when at red heat, the imprint of each blow is scarcely an inch in depth.

After the block has, in the same place, received one or more blows, its position is changed a little, and shortly its whole circumference is perceptibly thinner on a length corresponding to the breadth of the hammer. It is then pushed forward for a distance which equals that breadth, and the same operation is repeated until the entire length of the block is forged. It is then put into the furnace to be heated again, after which the same work of forging is renewed. But as the block soon becomes so long that the furnace cannot contain it, the difficulty is solved by heating half of it at a time, and when that half has been forged the other takes its place. It sometimes happens that in order to heat the middle of very long pieces, it is necessary to allow both ends to protrude from the furnace. Of course, with very large blocks forging is a lengthy operation.

Let us now turn to "Max," the 20-ton steam-hammer, which is placed at the other end of the building, and is equipped with the same number of furnaces and cranes as the big brother "Fritz." We find him occupied in working on a prism of steel, 18 metres in length, and weighing 10 tons, which is destined to serve as a drill to be used in the blasting at the Iron Gate on the Danube.

In addition to "Fritz" and "Max" there are in the workshop 30 steam hammers not honoured with names, some of which are, however, of very respectable dimensions. The added weight of the rams is about equal to that of "Fritz." We may here remark that there are in use, in other workshops belonging to the factory, as many as 84 steam-hammers, the added weight of their rams amounting to 84 tons.



MANUFACTURE OF COILED WHEELS

The large workshop on the left of Entrance No. 1 is an edifice of 130 metres in depth by 70 in width (425 feet by 230). Of course, it is impossible for us to stop at each steam-hammer and examine its construction, but we notice that there are here three specialities for which the hammers and their anvils have a particular shape and an especial installation. These are axles, wheels, and tyres for railroad cars.

Excepting those which are made of cast-steel, the wheel of a railroad car is composed of two principal parts, the wheel itself and the tyre. The wheels are sometimes solid, sometimes made with spokes. At Krupp's the latter kind is made in a special workshop; the wheel works are situated at one of the ends of the factory. As these wheels are also made elsewhere, we merely mention them and pass directly to the consideration of the disc wheel of forged iron, an important speciality of the Essen factory, and one which figures on the monument of Alfred Krupp. In this workshop we can follow the different phases of its manufacture. First a number of wrought-iron bars which cross each other are welded into a disc, of which the edges are thinner than the middle, where a hole for the axle is put. By a second operation this hub is fastened on a shaft. Then a bar of iron, **V**-shaped in cross section, is pulled at white heat from the furnace; the hollow side of this is placed on the circumference of the hub, around which it is wound three times. The end of the bar is flat and is given a fourth turn around the border of the disc. A wheel thus prepared is heated to a high welding heat in a wide furnace, and then welded under a specially heavy hammer furnished with a round head of the same shape and dimensions as the completed wheel. On the upper surface of the anvil, which is also correspondingly shaped, the wound-up wheel, now at white heat, is placed, being secured at its circumference by a strong hoop of steel. Then a few powerful blows press it into shape, and at the same time weld all its parts into one. The work terminates by an explosion. When the hammer ascends for the last time one of the workmen sprinkles water on the red hot wheel, and the next blow causes as loud a detonation as if a cannon had been fired. The unprepared visitor starts back in alarm, but the sooty boys at work grin with satisfaction. The trick has its use, for the suddenly developed steam carries off all scales, and the finished wheel leaves the anvil smooth and clean.

The tyres for car-wheels are manufactured in the same building. They are made of heavy ingots of medium acid open-hearth steel, or, if specially ordered, of crucible steel. After the ingots have been forged they are divided into short cylinders, of which the diameter about equals the length.

After being reheated these are flattened into the shape of a cheese, and a large hole is made in the middle. This is done by forcing a succession of steel truncated cones of gradually increased size through the metal by means of the-steam hammer. In spite of the violence of the operation no surface cracks are allowed. The anvil of the third hammer is provided with a short horn on which, after reheating, the rings are hung, and, whilst being slowly turned, are forged all round. The rings, now much widened, pass from here under yet another similar hammer, to be not only still further enlarged but also provided with a protruding border. Then the forging of the rings is completed, and they are transported on the railway to the tyre rolling-mill at the western end of the works. Let us follow them there.

The principal building belonging to Krupp's tyre rolling-mill is 100 metres deep by 60 metres in width. The middle is occupied by two trains of rollers and their large driving-engines. One of these, built by Alfred Krupp himself, was the first of its kind ever made. A certain feeling of respect is mingled with the curiosity with which we examine its rather complicated construction. For who can say how many millions have been gained by this machine? The other train of rollers is much newer and of simpler design. It consists of one fixed vertical steel spindle with an upper cylindrical tenon protruding over a fixed platform and carrying a steel roller, the profile of which corresponds with that of the outside of the tyre when finished. A second spindle is parallel to the first one, and, being movable, can by a hydraulic piston be forced nearer to it. The upper tenon of the second spindle carries the second roller, the profile of which corresponds with the inside of the completed tyre. Now, if one of the forged rings is slipped on the movable roller, and this is pressed towards the fixed one, it will continue to turn between the two rollers, becoming gradually thinner in profile and larger in diameter until the desired dimensions are reached. Two vertical and three horizontal guide-rollers serve to keep it in place and to preserve its circular form. Another roller, in contact with the inner surface of the tyre, by means of a system of levers, indicates its diameter to the fraction of a millimetre on a dial which can be viewed from a distance. The tyres made on the older style of rollers are, while still incandescent, placed on a press to be centred, and to have their circular form perfected; whereas from the newer rollers the tyres issue accurately circular, and require no further centring. The forged rings are, it may be added, heated in eight Siemens regenerating furnaces, the heating-chambers of which are placed beneath the floor of the shop which, through this economy of space, acquires a very open and roomy aspect.

The output of these works, which have played so important a part in aiding the development of Krupp's factory, amounts even to-day, when the invention of seamless steel tyres has long since ceased to be private property, to 20,000 tons per annum. Most of the tyres leave this shop as they are, and are put on the wheels at the railway workshops, car and locomotive works. The factory, however, also turns out complete sets of wheels for both cars and locomotives.

Near the tyre rolling-mill stands a machine shop for sets of axles and wheels. This is a new, bright workshop, 150 metres deep, which, with its long rows of fine machines, conveys an impression of the most perfect system and order. Here the tyres are first turned true on their inner surface, and the wheels on their outer surface, the diameter of the former being left slightly smaller than that of the wheels. The tyres therefore can only be put in place when expanded, by being heated to a certain fixed degree; the shrinkage which occurs later pressing them as fast to the wheels as if forming part of the same piece. Then the hubs are turned and bored true, and are by hydraulic machines pressed on the axles, which have also been turned true on special lathes. Finally the complete set is put on a lathe, and the outer surface of the tyres obtains its exact measure and form.

CHAPTER XII

THE ROLLING-MILLS

ALTHOUGH applicable to manifold uses, the hammer is none the less a slow worker. The greater the length of the piece to be forged, the more evident becomes this defect. To obtain elongated shapes of equal cross section, technology has at its disposal a far superior, and much more productive mechanism, viz., the rollers. These do not, moreover, perform their tasks by means of successive shocks, but by a quiet pressure applied during rotation.

The rollers used to manufacture narrow strips or plates are simply smooth cylinders. Two of them are placed parallel, and one above the other in a strong frame, and are by steam power turned in opposite directions. The space left between them is a little smaller than the thickness desired for the plate; and as soon as this is pushed into the wedge-shaped space between the rollers it is seized and pulled through. Then the upper roller is screwed down a little closer to the lower, and this operation is repeated until the plate is reduced to proper thickness. It will evidently have been stretched almost exclusively in the rolling direction. Therefore, to make a wider plate, this must be turned at a right angle several times, so that the long side may pass through the rollers first.

The rollers used to make bars, rails, and girders, are furnished with grooves and coils which fit on and into each other, leaving openings through which the piece must pass. Rollers of this description remain at an unvarying distance from each other, but the calibres or openings between them

A. Morlan pinx.

Meisenbach Riffarth & Co. Berlin, heliogr. & impr.

ARMOR PLATE ROLLING MILL

have decreasing cross sections, calculated, according to fixed rules, by special experts.

If only one pair of rollers is used, both turning in the same direction, the piece must, after every passage, be handed over the top roller, which can, of course, only be done well with small short pieces. There are two ways of avoiding this inconvenience; the pair of rollers may either be reversed after each passage of the piece, or else three rollers are arranged, one above another, the piece being sent between the middle and lower rollers in one direction, and returned between the middle and upper rollers. With a triple roller train of this kind, running always in the same direction, an ordinary steam-engine can be used. This is provided with a heavy fly-wheel, which takes up the energy, and then restores it when the rollers grasp the piece; an advantage partly counterpoised, it is true, by increased friction, and the necessitated use of lifting machinery. Also the immense accumulated energy of the fly-wheel is an unbound force of Nature, which in case of disturbance or accident, is apt to prove extremely disastrous, whereas the reversing rollers are completely under

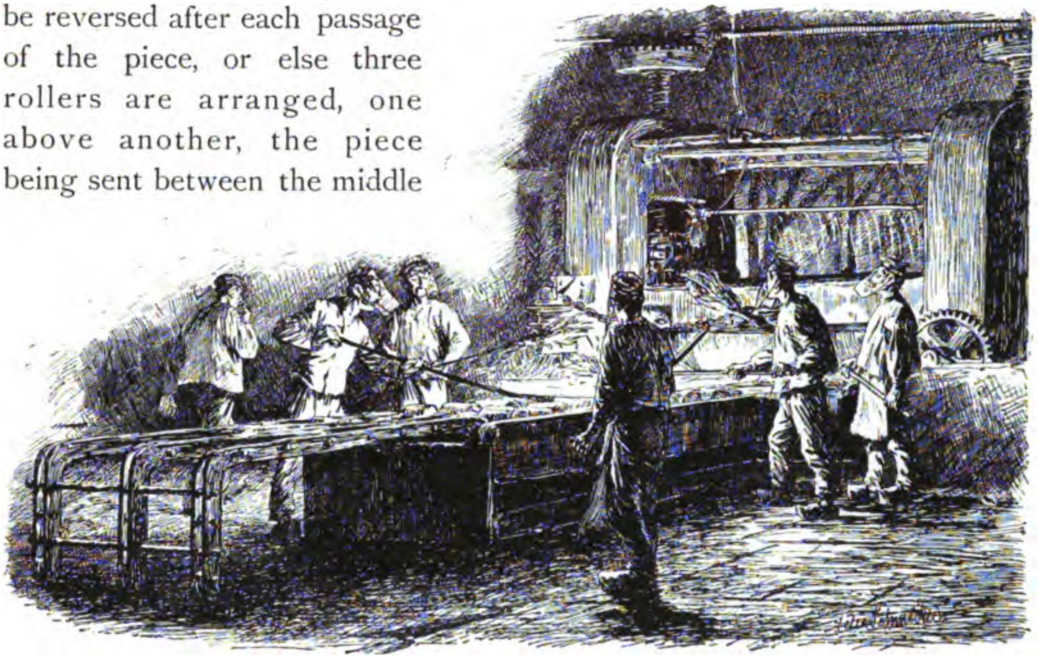


PLATE ROLLING-MILL

the command of the engineer, and the piece does not have to be either lifted or lowered. These, however, require a very powerful two-cylinder engine, which uses a great deal of steam, because the advantages of expansion and condensation cannot be fully utilised. These two rival systems have been for many years in competition. Continental engineers, numbering amongst them Alfred Krupp, advocated the "Trio." Of late years, however, the reversing trains have gained many friends.

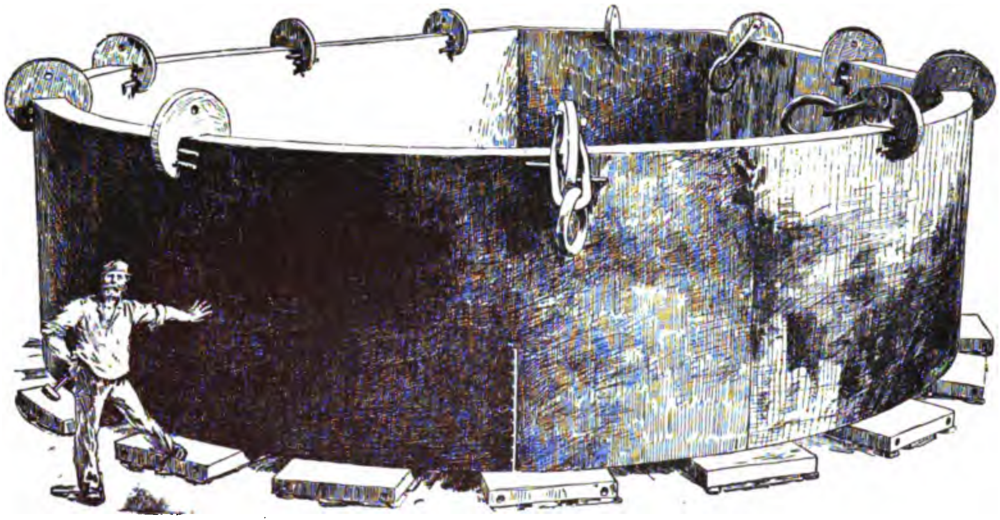
In Krupp's factory there are running no less than twenty-two rolling-mills, some of which we have already seen in the puddling shop, and near the Bessemer house. With the exception of the new armour-plate rolling-mill, all of them are "Trios," and are equipped with excellent steam-engines having Corliss gearing. Amongst the entire number, the rail rolling-mill produces the largest output. In the large building next to the one which contains the hammer "Fritz," are two similar "Trios"—each one having a 1600-h.-p. engine—which, as a general rule, work alternately, and not simultaneously. After a preparatory rolling in the Bessemer shop, the ingots are heated to yellow heat, in five large Siemens furnaces, and are then passed from thirteen to fifteen times between the rollers. And, as they issue in the form of rails, which continue to increase in length, they are caught by the short arms of long levers. These, being suspended on wheels, can be moved at will by the workmen, who must run alongside the rails, and, towards the end of the operation, this is not an easy task. At last the rail, like a great fiery serpent, glides from the finishing calibre into a trough and upon automatic rollers which lead it to a circular saw. As if cutting wood, this saw removes the uneven ends of the rail, and divides it into two or three pieces, of the proper length for railway tracks. These pieces pass through a system of straightening rollers and, by a mechanical arrangement, are then carried sidewise to the cooling-off place. From there they are transported on rollers into the adjoining adjusting-shop, where, by an eccentric press, their straightness is again accurately corrected. By milling the ends the rails are reduced to the exact length desired, after which the screw-holes for the fish-plates are drilled. Then they are taken to one of the receiving places in front and rear of the building, and after being stamped by an inspector, are, without delay, loaded on cars in readiness to commence the journey to their final destination.

THE ROLLING-MILLS

The daily output of this plant is 1600 rails of the usual length, that is to say, five miles of railroad track.

In the southern part of the factory stands the so-called spring steel and fish-plates rolling-mill, the manufacture of those articles forming part of its current task. It has three complete roller trains, of which the strongest, equipped with a 600-h.-p. engine, makes light rails and the heavier kinds of angle iron, also shapes for ship-building and similar purposes. Connected with this shop is a large adjustment room, where the bars are straightened and cut, the rails drilled and milled, the fish-plates punched and finished. In consequence of the variety of shapes, suited to numbers of purposes, which are produced by the rollers, there are done in this room a great many different kinds of work.

Here we finish our walk through the long succession of those workshops of Krupp's, busied almost exclusively with material for the most important modern peaceful accomplishment: two-thirds of the whole output of the giant factory consists in rails of the tracks that unite nations and their interests by bonds of steel; in axles, wheels, and tyres for the transport and exchange of the nations' wealth; and in elastic steel springs to allow mankind to travel comfortably all over the globe with the speed of birds.



ARMOUR TURRET FOR AN IRONCLAD SHIP

CHAPTER XIII

THE ARMOUR-PLATE ROLLING-MILL AND THE PRESS-HOUSE

IN 1864 Alfred Krupp began to make plates of iron and of steel. At first chiefly undertaken to supply the needs of the factory, their manufacture, owing to the establishment of two new roller trains, took, twelve years later, a prominent place among the productions of the Essen steel works. Three triple-roller trains, for making plates of from 0·5 millimetres to 75 millimetres (0·02 to 3 inches) thickness, occupy the spacious building behind the great hammer "Fritz." The largest of them has cylinders of three metres working length, and together with the second roller train is driven by an engine, of which the steam cylinder is 1372 millimetres (4½ feet) in diameter. Roller tracks and almost automatically working lifting tables, serve for moving the plates to and from the rollers. In addition to all grades of fine plates down to one-fiftieth of an inch in thickness, these rollers also turn out boiler plates, locomotive frame plates, and deck armour, up to a length of 11·5 metres (37·75 feet).

Soon after the death of Alfred Krupp, the construction of a new roller plant for manufacturing ship's armour of all thicknesses was commenced. It, as well as the attached Martin furnace-shop, began to work in 1891. The two great forging presses, set up simultaneously under the same roof, were designed not only to somewhat relieve the over-burdened hammer "Fritz," but also to surpass it considerably in power. The armour-plate rollers, the open-hearth works No. 4, and the press plant, together with their boiler-houses and gas-generators of about sixty fires, form a separate great industrial establishment of the first rank, which it will take a full day to examine thoroughly. Its situation is on the high open ground in the southern part of the factory, lying between the road to Frohnhausen and the Government railway.

On entering, we are profoundly impressed by the size and beauty of an enormous building, 200 metres deep by 100 metres in width, entirely constructed of iron and glass, which is as light and bright as a conservatory. It is divided into two wide outer and two narrower inner aisles, separated by three rows of columns. We are informed that it takes eight men's constant occupation to keep the roof and windows clean; which fact helps us to realise the size of the building. And in spite of the many large engines, tools, furnaces, presses, and travelling cranes, as well as the two hundred busy workmen occupying the interior, that vast expanse appears deserted and almost empty. The pillars, made of thick riveted plates and angle irons, are veritable towers, each one having an interior ladder. At about twelve metres above the ground they support on brackets girders of extraordinary strength, which hold the rails for travelling cranes; and about three metres higher the beams supporting the roof are placed. The frames of travelling cranes, looking like heavy iron bridges, span the aisles from girder to girder; while upon these frames move cars carrying the machinery of the cranes. All the cranes are driven by means of a square shaft, extending the entire length of the building, by a twin engine placed at one end. By the aid of levers a workman, from his seat attached to a crane, can by short turns of hand-wheels govern all movements, separate or combined, of the said cranes, and can also stop, in case of necessity, the engine driving the square shaft. By this arrangement each crane can reach any part of the aisle in which it is placed. Two or more cranes can, of course, operate together. No other similar workshop in any part of the world equals this one in equipment, containing, as it does, nine cranes with a capacity of 75 tons each, and one crane with a capacity of 150 tons. To make their great power better understood the fact may be cited that the united capacities of the cranes belonging to "Fritz," "Max," and all Krupp's other steam hammers only amount to a total of 250 tons.

Now let us watch the cranes at work. In the open-hearth workshop in the south-east corner of the building they are about to cast a 60-ton ingot. Two 75-ton cranes are in action, and lower gigantic ladles into the pits behind the two furnaces. The outlets have been prepared beforehand, and when the stopper is forced back, two streams of incandescent metal of a bluish hue shoot forth, and in a few minutes fill the ladles. These are then hoisted and conveyed to the casting pit where the massive mould is in readiness to receive the steel. The stoppers of fireproof material which close the holes in the bottom of the ladles are simultaneously removed, and the metal, liquid as water, flows first into short conduits and from them into the mould. In half an hour the ladles are empty, and the mould is filled to the brim with steel which is beginning to solidify. We are informed that this block of steel contains several thousand marks worth of nickel. After being hammered or rolled, this nickel-steel of Krupp's unites the high elastic limit of steel with the toughness of homogeneous iron; but, on the other hand, it does not possess sufficient hardness to make it suitable for the manufacture of sharp-edged tools.

The two Martin furnaces with a capacity of 45 tons each also produce ordinary steel, and smaller ingots of homogeneous iron. For the latter purpose, a smaller pit lying near the main pit, and containing moulds of more modest dimensions, is utilised.

The armour-plate rolling-mill is placed opposite the Martin plant, and occupies the eastern third of both centre aisles. Its double cylinder reversing engine has not less than 3500 horse power, which by means of a forged cast-steel gearing, changing the speed from three to one, is transmitted to the rollers. These also are made of forged crucible steel; their united weight being 90 tons, and their working width 4 metres. The plates are automatically moved to and fro on platforms with wheels. Between these wheels are a number of steel cones, all or part of which can by hydraulic power be raised above the level of the platform, thus making it possible to raise and to change the position of the plate. A large Siemens furnace, placed opposite the mill and nearer the end of the building, serves to heat the blocks or plates. The high vaulted chamber of this furnace is 5 metres square; its hearth rests on a car running on rails, the full length of which can be pushed into a pit from whence the ingot can be drawn directly to the platform.

Behind the heating furnace, and near the pit just mentioned, is a large open-hearth acid furnace, furnishing the hard steel which is cast on the hot soft plate for the manufacture of compound armour.

We are just in time to witness the proceedings. The rollers are empty and moving slowly. The furnace door rises, and on the movable hearth the glowing yellow block emerges, radiating a truly volcanic heat. Four hooks are at once placed under its corners, and in a moment it is swinging in mid air, suspended by four chains from a large travelling crane, and is moving towards the platform, the hearth at the same time returning to its place in the furnace. The block, of the same kind as the one we saw being cast, is three metres square and three-quarters of a metre thick.

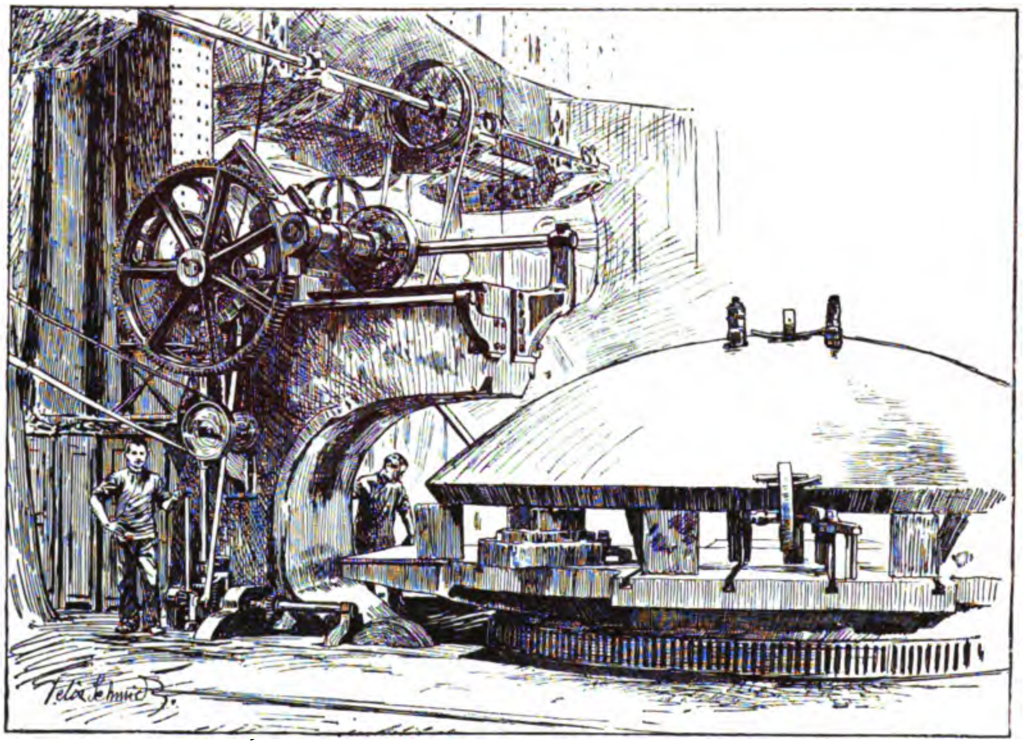
The rolling is done entirely automatically. All the miscellaneous work, such as gearing the rollers, driving the pumps and windlasses, and turning the screws to set the rollers, is performed by half a dozen independent, small auxiliary engines. The plate travels without interruption from one side to the other. From time to time it is turned, until it is four metres in width, after which it is only rolled lengthwise. After every passage it is indicated on a dial that the rollers by a few millimetres approach each other more closely. Therefore, before attaining a desired thickness of 300 millimetres, a plate must pass between the rollers more than one hundred times, which operation occupies about half an hour.

The process for removing scales is one which always interests and amuses visitors. Bundles of twigs are thrown on the plate, and with it pass between the rollers. The moisture these twigs contain makes each one explode, and a lively scene ensues. Great flames shoot forth from under the rollers, thousands of small bits of coal fly about, and the rapid explosions sound like the fire of a regiment.

These new rollers are also occasionally used to make large boiler plates. During one of the writer's previous visits to the factory he chanced to see rolled the 16-ton plate sent to the Chicago Exhibition. This was 32 millimetres thick, and measured 3·3 metres by 20 metres (1·26 in. by 10·82 ft. by 65·5 ft.), a size surpassing anything ever previously manufactured.

Such dimensions render it possible to make the largest ship boilers out of very few plates, and with only one line of rivets on their whole circumference.

After being rolled, the plate, still in a dark-red glow, is again seized by the crane, and transported to the bending press to be carefully straightened.



MILLING AN ARMOUR CUPOLA

The top of this press is made of a block of steel 2 metres thick, forming a table 2½ metres in width by 5 metres in length, which is supported by four cast-steel columns the thickness of a man's body. Below this upper table is a second one resting on the head of a powerful hydraulic piston, which, when the pumps work, is slowly forced upwards by a pressure of 5000 tons. The plate to be straightened is put between the two tables, and if it is to be bent downward, its ends are rested on two steel prisms, while a third one is placed in the centre on its upper surface. If, on the contrary, the bending is to be upwards, the two prisms are put on the upper surface of the plate, near the ends, while the centre prism is placed below instead of above it.

The same press serves to bend the prepared plates into certain rounded forms, fitting, for instance, the body of a ship. This, it may be mentioned, is a kind of work which often proves very trying to the patience of both engineers and workmen.

Behind the bending press we find thirty different machines intended for shearing, planing and drilling, all of which are new and of standard construction. Some of them are extremely powerful and of truly imposing size. One, worthy of especial notice as being a real marvel of mechanical skill, is a machine with eight circular saws, which simultaneously attack a plate in as many different places.

The world probably does not contain another smelting shop as well planned or as well built as this one. It stretches out like a map before us, and with a glance we are able to embrace the whole process of the evolution of the pig- and scrap-iron into the finished plate. The details as well as the totality of this establishment show such perfection, and are so completely up to date, that undoubtedly this branch also of the Essen factory must soon be granted a leading position.*

In the northern part of the building, known as the press shop, are the large new forging presses. With open space all about them, when viewed from a distance they look in this great hall like steam-hammers of medium size. Four cylindrical columns support a solid transom, from the under side of which protrudes an iron cylinder one metre in diameter which carries the hammer, while on the ground beneath rests the anvil. A crane brings from one of the open-hearth furnaces an enormous block of hot steel which is put on the anvil. The ram descends slowly and noiselessly upon the ingot, flattening it more than a blow from even the giant "Fritz" could do. The cylinder at once rises again, but only for a few inches, just allowing sufficient space to permit of the pieces being turned and moved forward, then another pressure follows. In this manner the forging continues, the rate of speed being the same as that of a large steam-hammer. But the silent working of the press makes less impression upon a spectator, as the slow and limited strokes of the cylinder do not indicate the enormous power by which it is made to move.

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* Written in 1894.

We remark that the upper end of this cylinder is like a piston and moves in a hollow steel cylinder affixed to the transom. It has a waterproof packing, and is forced down by hydraulic power. As it is a little more than one metre in diameter and the water enters above with a maximum pressure of 600 kilogrammes per centimetre square (8500 lbs. per square inch), it yields a pressure of five million kilogrammes—*i.e.*, 5000 tons. It is difficult fully to realise the magnitude of a force which could rend asunder the trunk of an oak two centuries old as easily as if tearing apart a bit of twine.

But it is not only the amount of pressure exerted which makes us marvel. This, one man could produce by pressing water into the cylinder with a small hand pump; the pivot would then, however, move so slowly that in an hour it would only advance a few millimetres. The extraordinary perfection of the forging press consists in the rapidity of its movements. Suppose that the machine makes, let us say, only twelve strokes a minute, and by each of them compresses the piece 50 millimetres (two inches), this would correspond to the work of 666 horses, while twelve blows from the hammer "Fritz," falling from a height of three metres (ten feet), only equal that of 400 horses.

To resist such colossal pressure all parts of the machine must be of great strength. The cylinder is made of gun steel, the four columns also are of forged crucible steel, while the transoms are composed of large steel plates, screwed and riveted together. Going below, we stand in a pit of masonry, and examine the framework in which the columns are encased, and which supports the anvil. With amazement we observe that while the press is in action this huge iron construction remains undisturbed, no bending being visible, nor any creaking audible, the gurgling of the water in the valves affording the only indication that the machine is in action. Involuntarily, we find ourselves wondering what would happen if one of these pipes were to burst, and a man should be hit by the projected stream of water. We learn that it would pierce him like a shot, and that if the stream continued its course vertically it would make a fountain mounting considerably higher than Mont Blanc. The pipes are, however, forged from the best material, and their walls, in thickness and tenacity, resemble those of small cannon.

The presses are provided with auxiliary hydraulic machinery. As the ingots to be forged are of different dimensions, and as the play of the piston is limited, it is necessary to be able to change the position of the upper transom. For this purpose the four columns are furnished with grooves into which fit steel bolts, fixing the transom at the height desired. Both the bolts and transom are moved by hydraulic power, a change in position being effected in a few seconds. The water for this purpose, which also serves to lift the piston, flows at low pressure from a separate pipe.

PRESS-HOUSE

The high-pressure valve, by means of an arrangement too complicated to be described in few words, opens only at the instant the ram touches the ingot.

The steam-engines serving the presses stand in large recesses on the sides of the building. Placed next to a small engine for the low-pressure pipes, is a fine, large, two-cylinder engine of 1000-h.-p., which especially attracts our attention, and from which, we are informed, the forging piston derives its power. The pistons of the two double-action compressors, which are in straight, rigid connection with the engine pistons, do not pump the water directly into the press cylinder, but into the cylinder of an accumulator. Constructed on the principle of a hydraulic press, this accumulator, by means of a piston several metres long, lifts a dead weight of 300 tons of cast-iron. As soon as the press seizes the piece the weight of the accumulator sinks, and the water beneath it with all its stored up energy enters the press cylinder. As long as the accumulator is down the pumping engine runs fast, and is stopped automatically as soon as the weight of the accumulator reaches its highest position. During forging this monstrous iron weight goes rapidly up and down, its inertia being, by its quick descent, added to the hydrostatic pressure, and, just at the proper moment, increasing the power of the press.

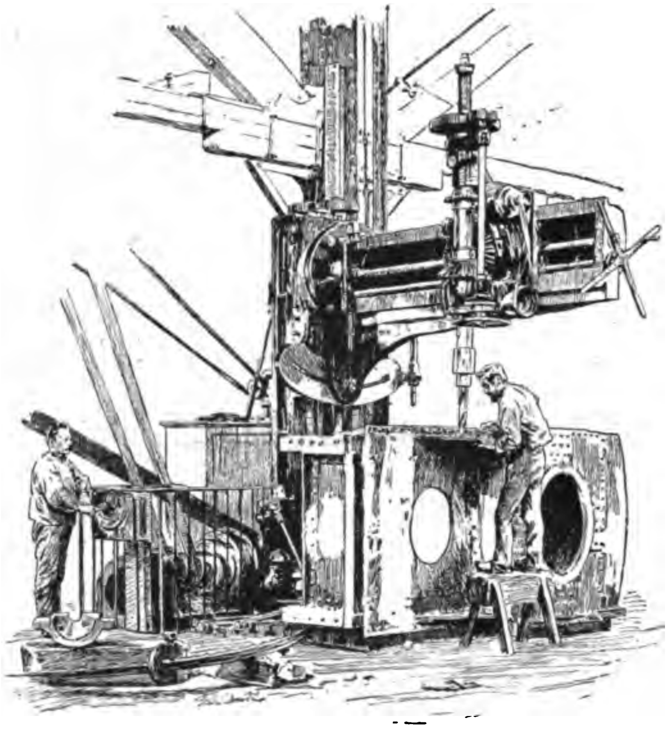
It must also be mentioned that the accumulator weight, instead of being supported by a single piston, rests on three, each one of which can be instantaneously put into action or shut off. By this arrangement the weight can, as desired, be carried either entirely by the centre piston, or by the side pistons, or else by all three of them. Thus, the working pressure can be made either 600, or 300, or 200 atmospheres; that is to say, 5000, or 2500, or 1666 tons; the maximum pressure only being required for the very largest pieces.

This brief description will, the writer trusts, convey an idea of the numerous organic parts composing a forging press, and of the ingenious system devised for the collection and transmission of energy. The construction of a steam-hammer is comparatively of, so to say, classic simplicity; but the hammer is in two respects at a disadvantage. In the first place it requires a very massive foundation, and an anvil block weighing several thousand tons; while its blows not only make a very disagreeable noise, but also create small earthquakes, which are alarming to people in the vicinity, besides having a disturbing effect on the foundations of all buildings standing near. In the second place the forging done by a steam-hammer is, in itself, imperfect. The hammer, as we know, acts by a sudden expenditure of its energy. If, for instance, a blow from "Fritz" falling from a height of three metres makes an impression of 50 millimetres on the ingot, that means that a resistance of 3000 tons has been overcome. But this enormous pressure acts only during one-eightieth of a second; consequently, it is not carried very far into the piece, the lower surface of which is, indeed, scarcely affected. On the contrary an enduring pressure of 3000 tons from the forging press acts all through the piece, compressing the metal between piston and anvil with the same intensity below as above.

It is for these reasons that, during the last ten years, forging presses have been gradually usurping the place of steam-hammers. The English manufacturers led the way, and several 4000-ton presses, as well as a number of smaller ones, have now been built.

Krupp's second forging press, standing in the same workshop as the principal one, has a capacity of only 2000 tons, but is in all other respects similar to the one described.

We leave this establishment firmly convinced that it is unequalled. And it produces all the stronger impression on us from being of recent construction. For old Krupp with his wonderful inventive genius, foresight and energy, was universally regarded as the head of the whole factory who could not be replaced; and people wondered what would happen to the leviathan when no longer controlled by his strong hand. But the new *régime* has now (1893) been tested for seven years. Despite some periods of commercial depression, large sums have been gained every year and have been used to make additions and improvements. A number of small shops and two large gun shops have been established, also three open-hearth plants, the great central electric station, and most important of all, at a cost of twelve million marks, the gigantic workshop to which we now bid farewell has been built. If Alfred Krupp could visit his former kingdom he would, with pleasure and admiration, acknowledge that under his son's rule metallurgical establishments have been founded and have flourished, which even eclipse those created by himself.



DRILLING MACHINE

CHAPTER XIV

SOME LARGE AUXILIARY WORKS. THE ADMINISTRATION

We have now, at the cost of considerable fatigue, systematically and pretty thoroughly examined the crucible, Bessemer, and open-hearth plants; also the forging and rolling shops. We find it somewhat difficult to classify in memory all we have seen, and to retain there a clear picture of even the most important parts. However, it still lies before us to inspect the mechanical machine shops, and, in particular, the gun shops, on which general interest is focused. But before we enter these establishments let us, by way of a recess, devote one day to a ramble requiring less close attention, during which we shall become familiar with some auxiliary plants.

SOME LARGE AUXILIARY WORKS

We must perforce leave unseen quite a number of blacksmiths', locksmiths', and repairing shops, working solely for the needs of the factory, many of which are, however, in their way, both interesting and important. Also, we are compelled to pass by the carpenters' and joiners' shops, contained in a large builders' yard, and, much to our regret, the repairing shops for full and narrow-gauge railway material, which are well worth a visit.

We will begin our tour at the brick factory, which lies in a declivity behind the armour-plate rolling-mill. This produces not only ordinary fire bricks of all shapes and sizes but also excellent quartz bricks, formerly made only in England, where they were known as "Dinas bricks." For making these quartz bricks a very hard native quartzite is pulverised by powerful stone-crushers and mills. This powder, after being mixed with a lime emulsion, is then pressed into bricks, dried, and hard baked. Magnesia bricks are also manufactured here from Grecian magnesite. Two large lime-kilns serve to calcine the dolomite which is afterwards disintegrated and mixed with tar, and forms the material for basic hearths. The output of this factory was, in 1892, not less than 42,000 tons of fireproof material. In this amount the consumption of the Bessemer works is not included, as that shop itself manufactures all bricks required for its own use.

Now, map in hand, we follow the road which passes by the West End Colony. It leads us to the new telescopic gasometer, of which the reservoir made of riveted iron plates rests on low pillars, and forms an open rotunda of 40 metres (131 feet) in diameter. We cannot resist the temptation of mounting the spiral stairs leading to the top gallery, and thus again enjoying another bird's-eye view of the factory and the attractive workmen's town of Cronenberg. The gasworks on the other side of the street number amongst the largest and best built in Germany. Quite near them a large heap of coal bricks attracts our attention, and we recall having seen similar black shining hills of patent fuel in several other parts of the factory. We are told that these form a reserve, which, in case of a strike among the miners, would provide for the needs of the factory until outside supplies could be obtained.

In order to reach to-day's chief point of interest—the boiler shop—we must cross the northern part of the factory, and on our way we pass the administration building.

This large four-storey edifice is built round an open interior court, and on all four sides measures 50 metres. Its present dimensions have been gradually attained during the last ten years; the addition of its upper storeys and other enlargements being indications of the increasing prosperity of the cast-steel works. Its high studded vaulted rooms and offices are well ventilated and comfortably furnished; they are lit by electricity and are connected with the telephone plant. On the doors of these rooms and offices a number of well-known names appear, for in this building is concentrated the government of the giant factory. Here, where all the wires converge, the disposal of immense sums of money is every day decided upon; here great inventions, destined to astonish the world, are examined, and here is cared for the welfare of many thousand people.

Let us try to get some idea of the complicated mechanism of this administration. In the first place it must be borne in mind that the Krupp factory is now and has always been the private property of one man and does not belong, as is often imagined abroad, to a stock company. The head of the firm is, within the limits of his enterprise, absolute master. In all questions arising with regard to the management of any part of the whole vast concern, his opinions and orders are decisive. He is responsible for his actions only to his own conscience and sense of justice.

Krupp has, however, of his own free will, appointed a board of nine directors to assist him in the management of his business. One of these directors is made president and all of them have power of attorney. This board always has a certain number of assistants—at present three—who also sign by procuration.

The board of directors of the Fried. Krupp firm may be likened to the cabinet of a monarchy, only with the difference that in regard to all matters of importance it acts as a body; no one member being, in such cases, authorised to act independently. Not only are all questions of any consequence put before the board for common consultation, but two signatures, either from two directors, or else from one director and one assistant by procuration for another, are required to constitute the binding signature of the firm.

All outside business is transacted by this board of directors; and with regard to internal matters also, it represents the head of the firm in such a manner that no one has the right to question whether or not Krupp agrees with any decision made by it. A printed code regulates the general action of the board and defines the rights and duties of its members. Another code gives the rules which govern the whole administrative body and states the positions and appointed tasks of all its different members. Beyond this all bureaucratic ways are unknown in the official, as well as in the private intercourse of Krupp's employés, all of whom from high to low are inspired by a feeling of good-fellowship.

Krupp's whole factory is divided into about one hundred departments, each one of which is managed by a chief and his assistants, the relations of these different departments with one another being like those of completely independent concerns.

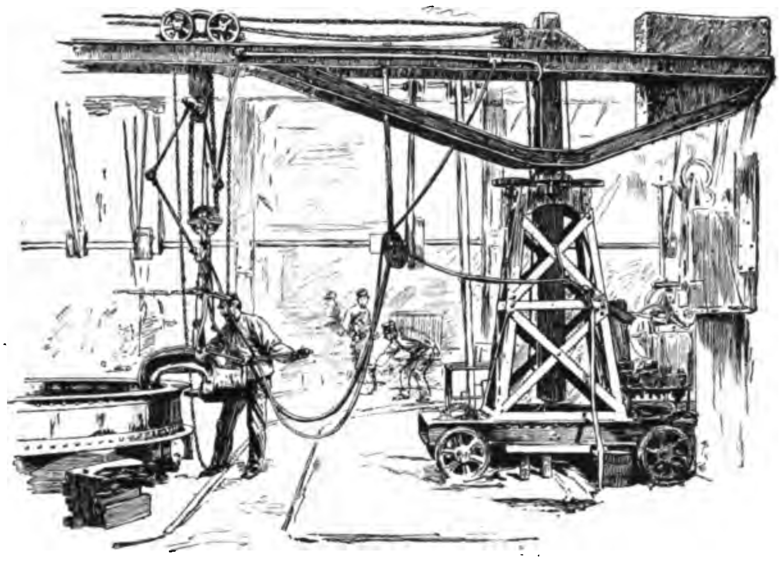
Placed directly under control of the board of directors are certain technical, commercial and administrative offices, as are also some miscellaneous institutions devoted to the needs of the factory—such for instance, as the fire brigade, the gas- and water-works, boiler-plants, and a few laboratories. The different metallurgical and gun works are, on the other hand, divided into a number of groups called "Ressorts," each one of which is managed by one or two responsible chiefs. The duty of these chiefs is to inspect personally all parts of their "Ressort," to decide contested points, to suggest ideas, and generally to endeavour to develop and improve the works under their charge. They must, of course, also maintain a strict discipline, and while carefully supervising the "Ressort," as a whole, yet not waste time by devoting too much attention to details of secondary importance. These chiefs of "Ressorts" act as intermediaries between the heads of workshops and the board of directors, always also keeping the board well informed as to the condition of their own divisions.

Fearing to weary his readers by further details, the writer will content himself with this very brief survey of the management of the great cast-steel factory.

Let us profit by the noon recess of one hour and a half, seizing this opportunity for lunching in the restaurant provided for Krupp's employés, which is conveniently situated on the ground floor of the administration building. As usual, the bill of fare consists of two kinds of meat with vegetables. Our amiable guide treats us to an excellent luncheon of cabbage and mutton, accompanied by a bottle of table wine, and for this he charges himself in the book with an almost ludicrously small sum. We drink his health and with renewed strength continue our walk.

Our most direct path leads us through the crucible shop. There all is quiet, as three hours must yet elapse before the casting will be done. We glance at the generator from which the Siemens furnaces obtain their fuel gas, and, passing beneath an arch of the circular railway, we emerge from the building.

Our attention is next attracted by a large four-storey building, looking somewhat like a barrack. This is the much discussed workmen's boarding house, built by Alfred Krupp. All the dining-rooms are filled; and we almost regret having already eaten such a hearty luncheon, for the lentil soup and pork smell very appetising. In addition to its restaurant and sitting-rooms, this house contains 800 beds for unmarried workmen. It will, however, be more fully described in the last chapter of this volume.



HYDRAULIC RIVETING MACHINE

On the other side of the street is the entrance to a group of workshops covering several acres. We have at last reached the boiler shop with its auxiliaries, where all sorts of construction irons for buildings and bridges are made. In every part of Krupp's establishment we meet with the products of these shops; for instance, all the supports of the enormous building containing the armour-plate mill, and the forging presses were here manufactured. We now find a number of armoured turrets for Krupp guns being made, and we also see a large steam-boiler which is approaching completion. This is suspended by chains, and a big steel plate, bent into a cylinder is, by means of a transportable hydraulic riveting machine, being secured on its length. In the yard, also, boilers both old and new are being hammered and riveted. At the blacksmith's shop, a plate an inch thick is, by a powerful hydraulic press, transformed before our eyes into a shallow bowl, four metres in diameter, surrounded by a flange. This is destined to serve as an end piece to a boiler. There is also at work a very interesting hydraulic press, with three pistons working horizontally towards one centre. There is an urn-shaped vessel in it, the neck of which is being further compressed by the pistons. In an adjoining workshop we are shown similar vessels all turned and finished. We learn that they are centrifuges for dairies, and that they represent a Krupp speciality.

We return by Borbeck Street, where we are still on Krupp's territory. On our left open several streets lined with dwelling-houses for the foremen and workmen, and with school-houses for their children, which streets lead to the large workmen's colony known as Nordhof. When opposite the monument of Alfred Krupp we again take the Limbeck Road, and after following it for a short distance, passing on our way a new boiler-house 200 metres deep, we reach to-day's last stopping-place—the iron foundry. This is one of the largest and best constructed of its kind, while its annual production is, we are told, 16,000 tons.

On entering it through the high portal under the eastern gable, we are particularly impressed by the moulding and casting shop, 120 metres deep by 40 metres in width. In it a casting pit is surrounded by four powerful cranes of peculiar construction, capable of lifting by their united power weights of 100 tons. In this shop, the heaviest pieces are cast and moulded; among other things, iron moulds weighing as much as eighty tons, intended to hold the large ingots of steel used for making armour-plates and cannon. We find the workmen engaged in casting a pivot plate for the carriage of a large coast defence gun; a very heavy and difficult piece, in all the dimensions of which strictest accuracy is necessary.

The foundry for projectiles at the other end of the building is also very interesting. In it are made all the dummy shot and shell, used in testing the guns, which are of exactly the same weight and shape as the steel ammunition for the guns in which they are used. So-called ring-shell for field artillery are also manufactured here in great quantities. These shell have an interior body of toothed cast-iron rings, half an inch thick, placed above each other to form a short, grooved column, which is set like a core into the mould, the iron which is to form the exterior body of the shell being then cast around it. These shells, as we know, are when finished provided with a bursting charge, and an ingenious double-action fuse, which will explode either at a given time after firing, or else on impact with the target, the projectile then breaking into several hundred sharp edged pieces and creating a perfect hail-storm of iron.

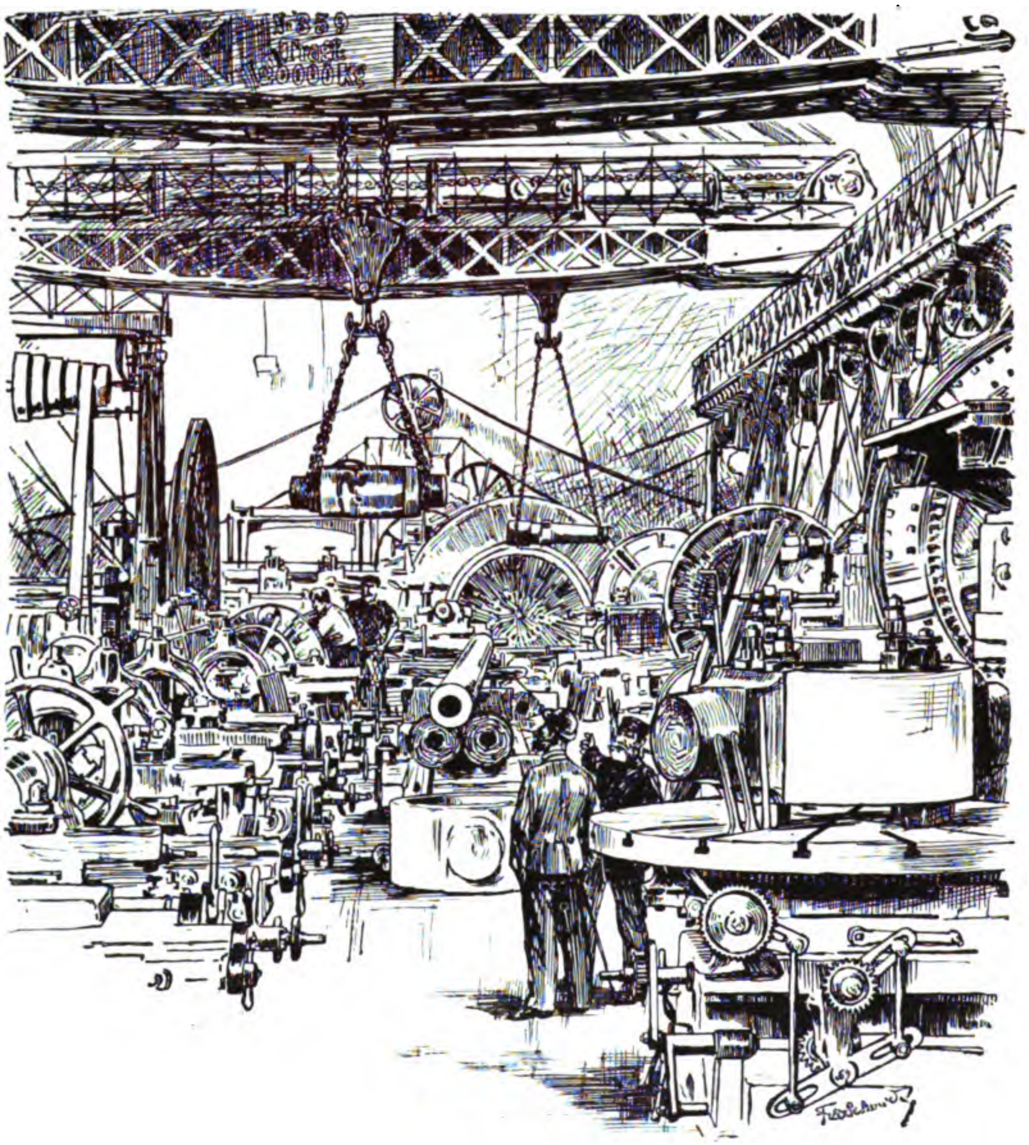
But the day is drawing to its end, and in spite of our resolution to make it one of partial repose, we again find ourselves tired out both in mind and body. However, a pleasant evening in cheerful company, seated round the big oaken table in the hall of Krupp's casino, with a good bottle of Rhine wine before us, will soon make us forget its fatigues.

CHAPTER XV

THE MACHINE SHOPS

INSTRUMENTS and machinery, for which accuracy of shape and dimensions as well as a smooth surface and fine appearance is of importance, can, by forging or by casting, only be made in the rough. They receive their finish in special workshops by means of tools of stone or of hard steel, which cut, scrape, or grind off particles of their surface. To accomplish this, the cutting-tool must be carefully held and moved in a very regular manner. Originally, this tool was always held in the hand. But even in very ancient days certain machines were invented which regulated its movements. Since then the improvements in machine tools have kept pace with the progress made in mechanics. And yet, to-day, even in the largest establishments, supplied with all the best and newest modern appliances, there is still plenty to occupy the hand of a skilful workman. And this will always be so, for the file is a cheap and convenient tool, fitted for a great diversity of uses. Its importance, as well as the activity of Krupp's workshops, is demonstrated by the fact that the latter require about one thousand new files daily. These are made within the factory, in a separate, well-equipped workshop.

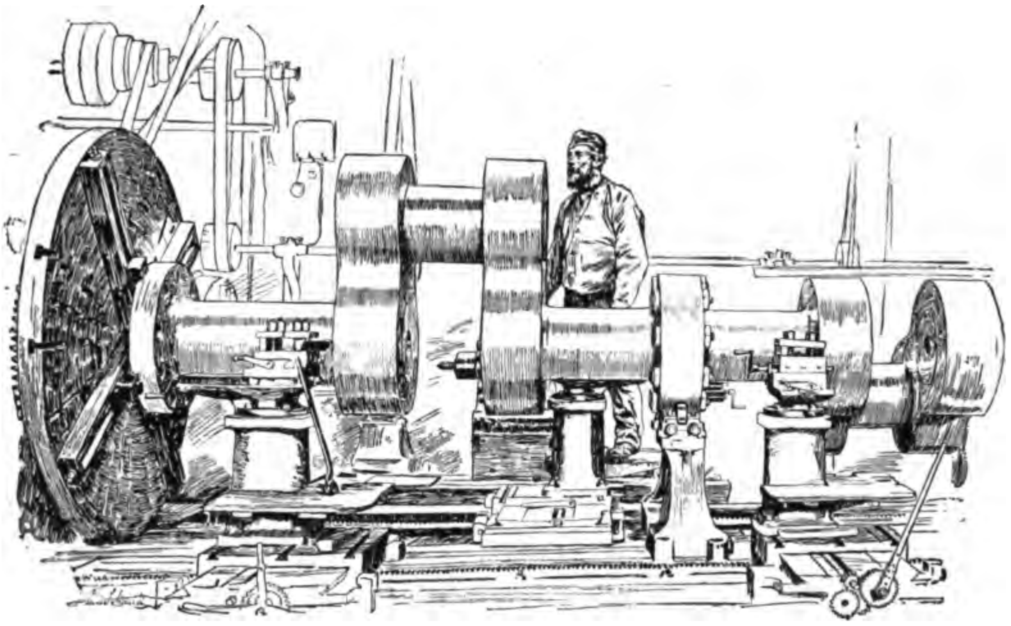
Now, let us enter the labyrinth of machine shops, which is close to the administration building. The shops form a group of ten, each building being several storeys in height. In all of them the heavier tools are found on the ground-floor, and the lighter ones on the storeys above. These buildings are approached by narrow and standard gauge railways, are furnished with strong elevators, and have their upper floors connected by bridges.



MACHINE SHOP No. II

In the interior of the workshops large travelling cranes, which are supported by the walls and columns, serve to transport heavy pieces from place to place. All these shops are well lighted and ventilated, and are kept scrupulously clean, so that after the heat, dust, and blinding lights of the forges and foundries, we feel, when we enter them, as if we had been transported to a new world. But here it is, we must admit, a little difficult to accustom ourselves to the confusing multitude of shafts, belts, pulleys, and wheels.

Among all the tools in Krupp's machine shops, the turning-lathes, numbering eight hundred, take precedence in importance. A lathe being a very familiar tool, we shall only notice the largest of them. There is one of these, stretching across almost the entire length of a building, which has seven sliding-rests to prevent the pieces from bending, and which is used to turn cannon-tubes, as well as shafts of all weights, and of up to thirty metres (100 feet) in length. On another we see a ship's shaft with three cranks, weighing forty tons. The lathes for turning crank-pins and gun-trunnions are peculiarly constructed. In these the tool is fastened to a rotating ring, the workpiece being fixed in the centre. There is also a great number of big



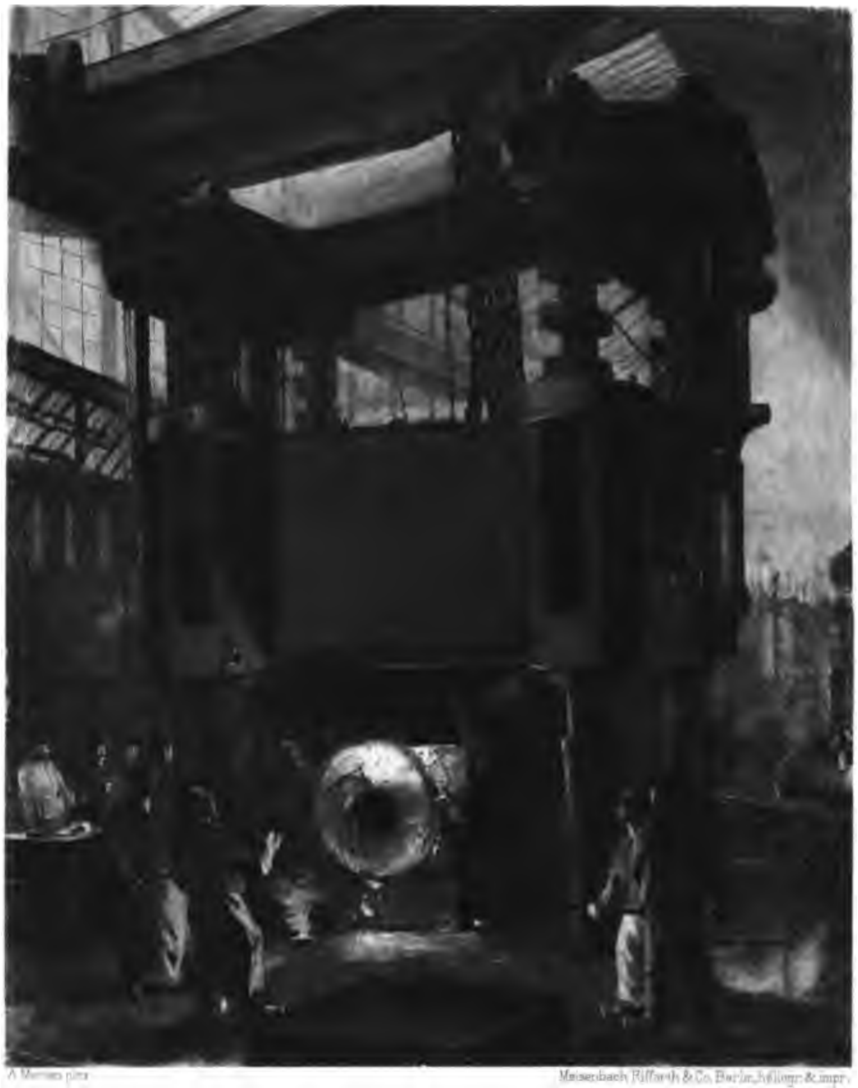
PART OF A CRANK SHAFT ON THE LATHE

surface lathes, many of them busy on large steel hoops for built-up cannons, which must be drilled and turned with the utmost accuracy. It sounds almost incredible, but the writer has seen a lathe at work in machine shop No. II, of which the face-plate was fourteen metres (46½ feet) in diameter. If this plate had been stood endwise next a four-storey house it would have reached as high as the roof. And in the same shop there is a smaller lathe with a face-plate measuring ten metres in diameter. These enormous surface lathes are used on the circular rails of large gun-carriages and also as, so to say, continuous planing-machines, working with four tools at a time, on a certain number of similar pieces.

Next in importance to the lathes stand the boring and drilling machines. In addition to two hundred such machines of the ordinary construction, we also see a number of doubles and multiples, some of which are particularly interesting from the fact that they not only automatically regulate the distances between the holes but also the inclination of the holes.

Further on, our attention is attracted by the cannon-drilling machines. At Krupp's no gun tubes are forged hollow, but all are bored out of the solid block. The drill used for this purpose is not shaped like those which convert into scraps the material cut off. It is a hollow cylinder, having at the end six cutters. It cuts an annular hole, leaving in it a cylindrical core which enters into the hollow tool. Then the drill remains motionless, while the cannon slowly rotates. The before-mentioned 30-metre lathe permits of drilling pieces 15 metres in length, or, if used from both ends, of 30 metres. A hollow-cast steel shaft, 25 metres long, which was shown at the Chicago Exhibition, is an illustration of the work which this unique machine-tool can perform.

Another rotating tool, fitted for manifold uses, is the milling machine. This has a solid steel cylinder, covered by cutters which resemble the teeth of a circular saw. When a piece is pressed towards a rotating tool of such construction, it will be hollowed out accordingly, and when the piece is moved past the tool, it will receive a groove, the cross-section of which will correspond to the face of the tool. If, for instance, the milling-tool is a cylinder with straight cutters, and the piece moves under it tangentially, the result will evidently be a plain surface. Or if that same tool is moved round the edge of the piece, following a certain curve, the edge will be milled straight and shaped accordingly. A thin milling-cylinder with cutting

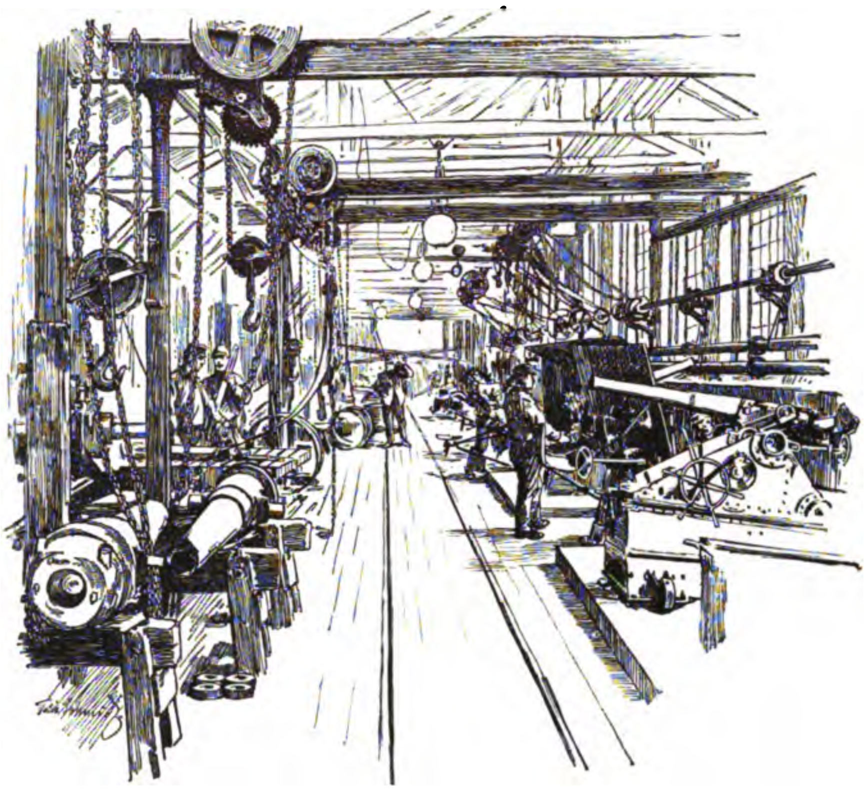


A Menzel pinx.

Meisenbach Riffarth & Co. Berlin, heliogr. & impr.

5000 TONS HYDRAUL. FORGING PRESS

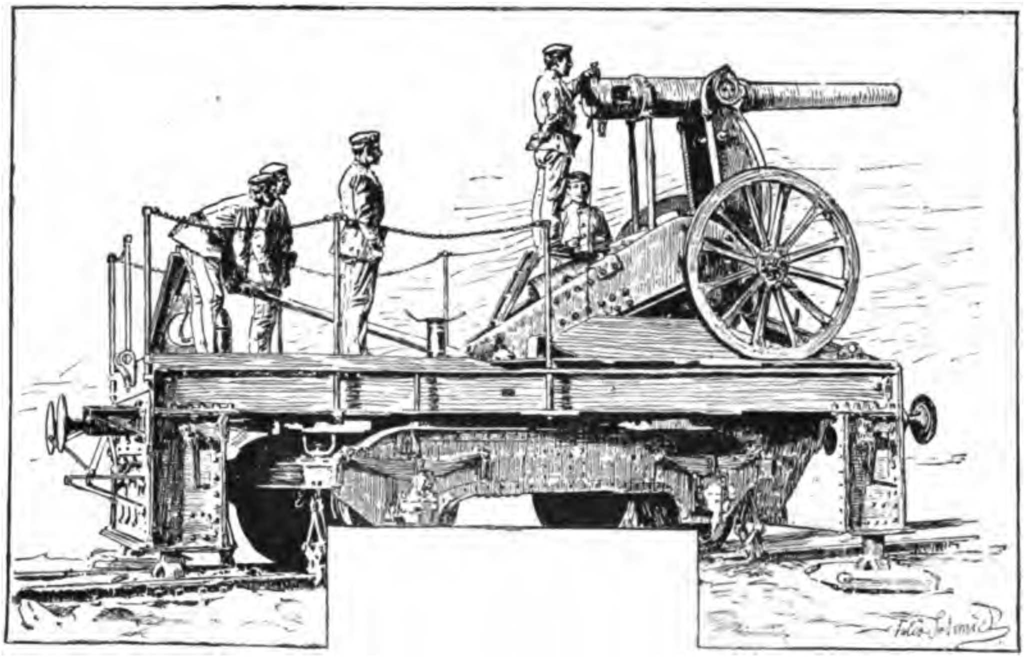
edges on its head and sides would make a groove which could be broadened at will by a sidewise movement of either the tool or the piece. Such is the principle of milling-tools, with which large rooms at Krupp's works are filled. They are especially useful when many small pieces of the same irregular form are to be shaped; they also cut the teeth of gearing-wheels and of worm-wheels, such as are required for the mechanism in gun-carriages to lay the rapid-firing guns. A marvel of mechanical construction is the large milling-machine in machine shop No. 11, which, in our presence, cut a 20-ton geared roller for the plate rolling-mill from a solid cylinder of cast steel. The gearing-teeth were cut oblique, and their complicated shape was developed with perfect accuracy. Any one can understand what a difficult task was then accomplished.



GUN-CARRIAGE SHOP

To these three great classes of machine tools, having rotation as their principal movement, is added a fourth class—the planing machines—for which the piece to be planed is bolted to a table moving horizontally to and fro. The cutter is attached to a support, and after every passage of the table moves a short distance laterally. The more complicated planing machines permit the support to be inclined in such a way as to make it possible to plane oblique and vertical as well as horizontal surfaces, and thus to produce prismatic pieces of any given cross section. These planing machines are less numerous than the rotating machine tools, the largest of the kind with tables of 20 metres by 6 (65 feet by 20) are to be seen in Krupp's armour-plate mill. In one variety of this machine, in place of the piece worked, the tool makes the movement, which is usually either vertical or oblique. For these grooving and slotting machines the piece to be worked is fastened on a table, which can be moved into all possible positions; the machines can therefore be used to produce plain as well as cylindrical surfaces. In addition to planing the sides of cranks for large engines, and to slotting wheels and pulleys in those places where the keys which fix them on their shafts are to be put; to these machines is also entrusted the important task of cutting in guns the breech openings which receive the fermeture wedge. Also, in many cases, they take the place of a saw, and cut off the superfluous parts of a piece, or else cut one in two. Crank shafts, for example, come from under the hammer with broad wings, and do not assume the appearance of cranks until a piece in the middle has been slotted out.

After our review of these world-renowned shops, where thousands of workmen, by means of 1400 machines driven by engines with a total of 3350 horse-power, shape and finish all the various cast-steel products, we deem ourselves sufficiently prepared to turn our attention to their most remarkable work—the guns.



TWELVE-CENTIMETRE (5-IN.) SIEGE-GUN MOUNTED IN DISAPPEARING CARRIAGE ON TRAVELLING PLATFORM

CHAPTER XVI

KRUPP'S GUNS

GUNPOWDER and modern explosives derive their terrible power from the faculty which they possess for being changed almost instantaneously into gases of several thousand times their own volume. This chemical reaction, commonly called explosion, must, through ignition, be induced by some external cause. This usually demands little physical power, but merely the direct or indirect intervention of man's initiative. Thus this property enables man to unchain at any moment that slumbering energy which powder contains, and to force it to do mechanical work.

As a matter of course, as soon as this faculty was understood, powder was used for the purposes of war. For things which could not be accomplished by the strength of an arm or the elasticity of a bow, could be done by a thimbleful of that mixture of nitre, sulphur and charcoal, and to fell a Goliath from a distance became an easy matter.

The first cannons were heavy monsters difficult to move. They threw solid balls of stone or iron, and were only designed to destroy the walls of feudal castles or the ramparts of towns. But their use soon extended to the battlefield, where we hear of them in many forms and under odd names, carrying terror and death into the enemy's lines, not only by means of shot, but also by a hail of iron from bursting shell and bombs. The construction of the most ancient field-guns shows that at the time they were made the simplest natural phenomena were not understood, and that the power of gunpowder was still a mystery. But in the reign of Charles II. practical experiments commenced, and rules were established as to the proper length of guns of different calibres, and intended to be used for different purposes. At the same epoch, in accordance with the science and skill of the age, it was decided that bronze was the metal best suited for cannon. That this material proved an incentive to artists is testified by the beautiful old guns still preserved in our arsenals.

MOUNTAIN GUN ON THE MARCH

For three consecutive centuries the further development of cannon seems to have been arrested, in spite of the fact that in the conflicts between nations they began to play a more prominent part. Frederick the Great and Napoleon I. won their battles with an artillery which, according to our present ideas, was very primitive. But in the beginning of this century the invention and introduction of far-carrying guns for the infantry made the artillery see the necessity of improving their arm, and towards the middle of the century many carefully carried out experiments largely contributed to the development of a science of ballistics, and led to the construction of the rifled cannon.

Rifled cannon and small rifled arms have in their bore a number of grooves running in slender spirals from the chamber to the muzzle. These grooves cause the projectile, in its movement forward, to rotate around its longitudinal axis, and this rotation makes it possible to use a lengthened and pointed cylindrical projectile, which, not turning over, flies like an arrow, penetrating the air much more easily, going further and hitting harder than a spherical bullet of equal calibre. The first country to introduce rifled guns into its field artillery was France. She carried them into the Italian campaign of 1859, and to them her remarkable success was chiefly ascribed.

These new bronze guns were muzzle-loaders. This fact is noteworthy in view of what had even then been accomplished in the Essen cast-steel factory. For at that period Alfred Krupp had already constructed and tried that cannon—a cast-steel breech-loader—which was destined to conquer for him supremacy as a gun-maker. He has himself in a special monograph explained the principles which guided him in the construction of the breech-loading gun.

"*I abandoned,*" said he, "*the muzzle-loading system because I became convinced that it did not ensure the same accuracy of firing or facility in loading as a good breech-loading system. In muzzle-loaders a certain play, or space, between the projectile and the wall of the bore is necessary. Now this cannot but diminish the accuracy of firing, for the space allows the projectile to waver whilst travelling along the bore, from which an imperfect direction and inaccuracy in hitting must result. Moreover, time is lost by loading from the muzzle, and lastly, numerous accidents are caused by the gunner's lack of a means by which he can examine the bore to see if any burning residue is there. In breech-loaders this danger is avoided, as by opening the breech the condition of the entire bore can be controlled.*"

Although the superiority of Krupp's cast-steel as a gun metal, and also the advantages of the breech-loading system were admitted, yet financial and political reasons, and beyond all, a prejudice in favour of the old school artillery, for a long time upheld the bronze muzzle-loader. Nor was the part played by the Prussian artillery (only partly armed with breech-loaders) against the Austrians in 1866 brilliant enough to open the way to the general introduction of the new gun. All objections were not overruled, and the superiority of these guns was not universally understood, until after the Franco-German War, when friend and foe alike agreed in attributing to the artillery armed with Krupp's cast-steel breech-loaders an important share in obtaining the great successes of the German army. To-day, the armies and navies of all well-organised governments, not excepting conservative England, are provided with cast-steel breech-loaders.

MOUNTAIN ARTILLERY, CLIMBING

In this brief historical review, Alfred Krupp appears as the boldest, most persistent, and the most eminently successful pioneer of modern ordnance. Those workshops of his great factory which we are now about to enter were the birthplace of the high power gun. That fierce offspring of an iron age was here nursed with care and intelligence; and here it grew to be one of the mightiest mechanical forces on the earth. A peculiar feeling, which is almost one of awe, comes over us as we step into these halls where we shall follow all the stages through which a first-class gun must pass before it is perfected.

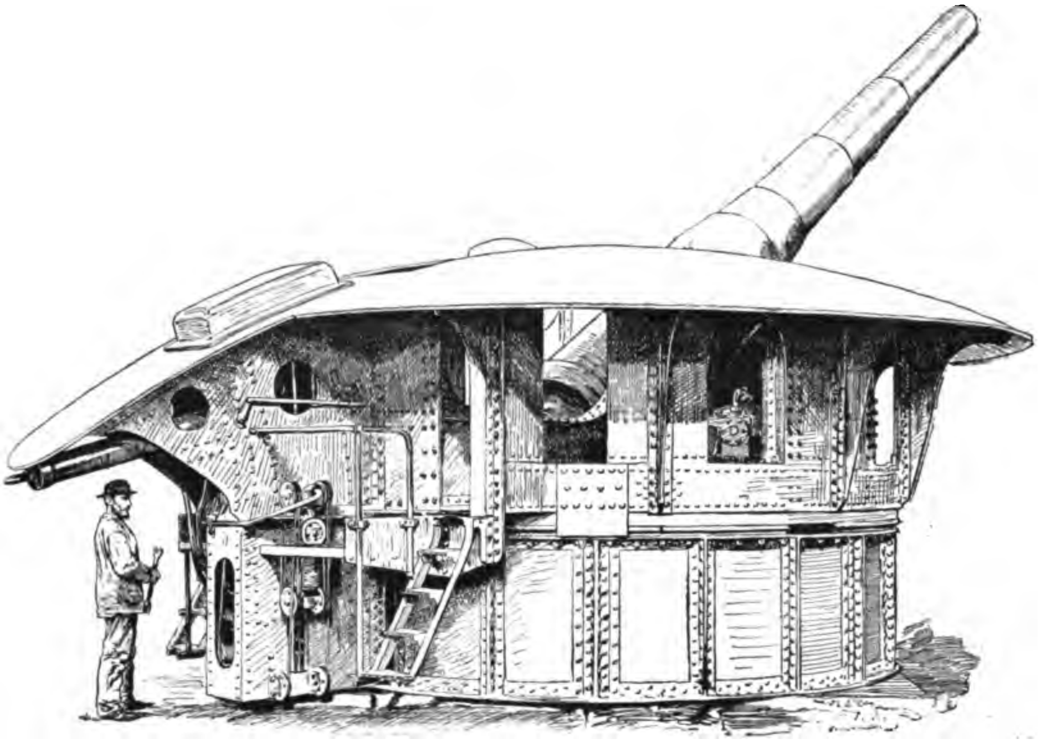
Our curiosity is much excited as we are going to see many things new to us; things which to outsiders like ourselves will be doubly interesting.

For in spite of all we have seen in going through the other departments of the factory, and in spite of all our endeavours to initiate ourselves into the mysteries of steel-making, outsiders we still remain. The writer has no intention, either in this chapter or in the next, of providing ordnance men with any data of especial value concerning the construction of guns; nor yet does he intend to furnish anything like a complete list of their many forms and uses. On the contrary, he repeats what he has said before, this book is intended for educated outsiders, and the writer's aim is merely to give a correct general idea of the modern cannon; certainly one of the most interesting products of man's industry, as well as the most formidable weapon of defence placed at the disposition of the nations. And so he invites his readers to accompany him through the ordnance department of Krupp's cast-steel foundry.

MOUNTAIN GUN CARRIED BY A MULE

When we enter, the first thing we learn is the fact that apart from the introduction of cast-steel and breech-loading, modern gun-making has, through the introduction of the hooped and built-up gun, been entirely changed; and has become a process of the greatest mechanical accuracy. A gun is no longer a simple hollow cylinder of steel, but consists of at least two parts, one of which is fitted into the other according to certain fixed rules.

Science and experience have demonstrated that single tube guns cannot, by merely increasing the thickness of their walls, be made to resist satisfactorily the pressure of the gas developed by heavy charges. This is because the metal next to the bore is strained to its utmost limit of elasticity, whilst the tenacity of the metal on the exterior is but slightly affected. Therefore a simple addition to the thickness of the wall will only strengthen a tube up to a certain limit. But this difficulty is surmounted by slipping over a comparatively thin tube a "jacket" slightly heated; which, as it cools, compresses the tube, while it is itself strained to about one-third of its limit of elasticity. The bore of a cannon constructed in this manner is therefore, when idle, in a state of compression; when the cannon is fired the gas produced must first overcome the said compression of the inner or **A**-tubes, on the tensile strength of which only the remainder of gas pressure works. At the same time the elasticity of the outer tube or "jacket" is better utilised and adds much to the total resistance of the gun.



TWENTY-EIGHT CENTIMETRE (11-IN.) GUN L/40 IN SEACOAST CARRIAGE WITH HYDRAULIC GEAR

In accordance with this principle all guns of small calibre consist of an **A**-tube and a jacket, those of large calibre of an **A**-tube, a jacket and one or more layers of hoops or coils.

Simple as the principle of built-up guns appears, its successful practical application was nevertheless a most difficult task, and one requiring the highest degree of mechanical precision. It called for the minutest investigations as to the laws of the extension of steel under the influence of heat and by mechanical strain The proper dimensions and temperature and best methods of casting, all of which are kept secret, had to be determined by long and complicated calculations verified by the practical experiences of the workshop and the proving-ground. Also the surfaces of the tubes which are by shrinkage brought into contact, must be machined with the utmost care and accuracy. As a convincing proof of this it suffices to cite the fact that, according to the teachings of physical handbooks, a cast-steel ring of 20 centimetres (8 inches) diameter only extends one millimetre (0·04 inches) when strained to its elastic limit. Successful results therefore depend on a hair's-breadth of exactitude.

As we have seen, every built-up gun is made out of at least two blocks of cast-steel; one of these is forged by steam-hammer or forging press into a long slender cylinder for the **A**-tube, the other, destined for the jacket, into a shorter cylinder of about double the diameter. For small guns the jacket-piece is given two short wings, to form the trunnions on which the gun rests in its carriage.

The short cylinders or hoops which on large guns are laid around the **A**-tube and the jacket, and of which one is provided with trunnions, are forged in the same manner as railway tyres, by hammers or presses, as previously described.

These forgings after being annealed are first roughly machined, bored, and turned to their approximate dimensions; they are then submitted to a sort of tempering, in order to give them the correct limit of elasticity. From the metallurgical point of view they are then finished, and it only remains to prepare and turn to their exact measure and form those cylindrical surfaces which will be brought into contact by shrinking the pieces together. The accuracy with which powerful lathes perform this task is shown by the following example; the shavings removed by the machine from a jacket of 75 centimetres (30 inches) diameter, do not curl in the usual way but form sheets 210 millimetres (8 inches) wide, which roll up like paper. Let us examine one of these sheets. It is perfectly homogeneous and elastic, and can be bent to and fro without breaking. But the most remarkable fact is that this sheet which, when unrolled, measures 1·6 metres (62 inches) in length, weighs 90 grammes only. Its thickness is, therefore, one-thirtieth of a millimetre or ·0013 of an inch, which is about one-third of the diameter of a human hair. Which shall we more admire, the quality of the steel or the perfection of this big lathe and its cutter?

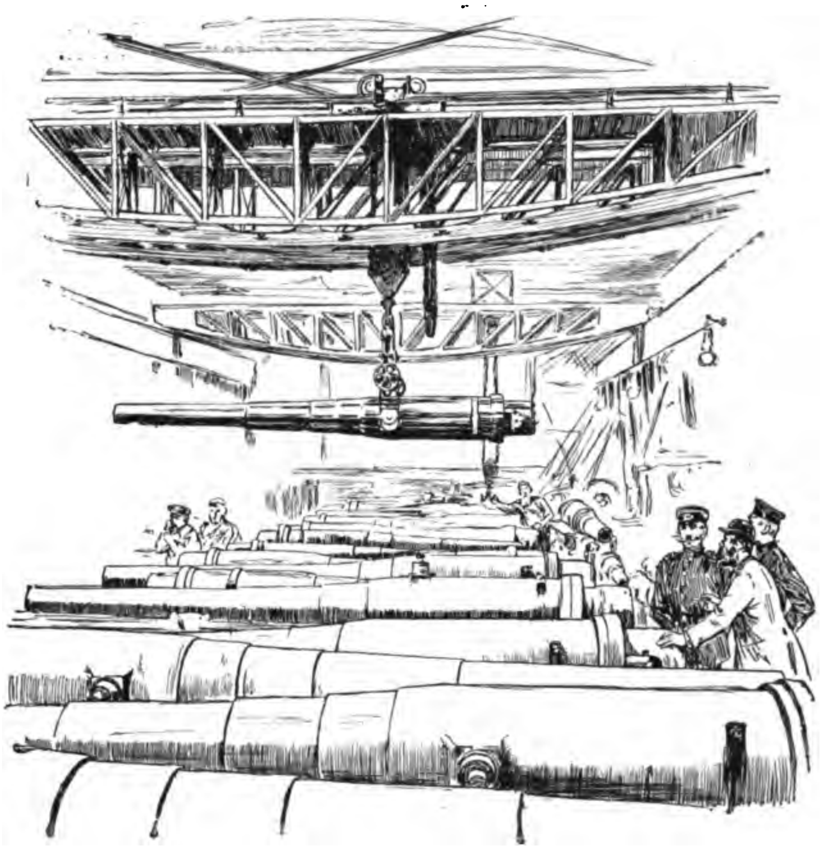
The finished tubes and hoops are taken to a special workshop to be united by shrinking as described above.

On examining the guns, we notice that when the jacket is fixed on the **A**-tube, the latter does not extend all through, but only reaches to where the jacket is to receive the breech mechanism; nor do the hoops on the jacket reach beyond this point. Thus, we may consider the jacket as consisting of two parts, one of which, the longer towards the muzzle, holds the **A**-tube, and the other, called the breech, holds the fermeture. This peculiarity of construction has great importance. When the gun is fired, and the projectile first moves inside the bore, the longitudinal pressure is entirely borne by the jacket, whilst the **A**-tube only has to resist the maximum radial pressure.

The gun is afterwards sent back to the machine shop, where it is finished on the exterior; the trunnions are turned, and the breech is machined to receive the breech mechanism. Krupp chiefly uses the wedge fermeture, the wedge being lodged horizontally in the wedge hole, an opening which crosses the breech end of the jacket. To make this wedge hole, a circular hole is first drilled, then widened, and shaped by a slotting machine. This done the gun is bored true and polished inside. We notice that the inner diameter is not the same throughout the entire length, but that the part next the breech, which receives the projectile and powder charge, is wider than the end which is rifled in order to guide the projectile on its way through the bore.

The last operation in the long series of stages through which every gun must pass is the rifling—*i.e.*, cutting in the bore those shallow spiral grooves which force the projectile to rotate. The rifling tool has a cylindrical head, bearing on its circumference a crown of radially adjustable cutters, which being formed like hooks, slide along the bore when the tool is pushed in, but cut grooves of their own width when being pulled out. The rod on which the head is fixed has several slots, running in spirals of very long pitch. By these the rod is guided so that in moving backward and forward it turns slightly round its axis, determining at the same time the winding of the grooves. After being cut, the grooves are ground true and polished. This is done by means of leather-covered wooden cylinders, dusted with emery powder, which by an endless rope and special machinery are drawn to and fro through the gun.

Krupp's expert inspectors examine and measure every gun in each of its stages, and again after its completion. The bore, especially, is accurately measured by delicate instruments; and its inner surface is inspected by means of an incandescent lamp and mirrors. Not the slightest fissure, the smallest hole or unevenness, is tolerated. If any such be found, the gun is pronounced unserviceable and its metal, as well as all the work spent on it, is wasted, causing a pecuniary loss which sometimes amounts to thousands of pounds.



IN THE GUN ASSEMBLING SHOP

Among those workshops where the guns and breech-mechanisms are finished, we will first visit the large new gun-shop No. 5, opposite to the administration building. This is an iron construction, which as an architectural feat is in itself worth seeing. It is provided with two travelling cranes of seventy-five tons capacity each. About one hundred terrible instruments of destruction are here lying peacefully side by side. We regret not finding any of the largest cannon ever made, of 40 centimetres (15·75 inches) calibre, 14 metres (45·93 feet) length, and 120 tons weight; we see however several of 30·5 centimetres (12·01 inch) calibre, 35 calibres length, and 60 tons weight, a type of gun which the armour of no ship afloat can resist, at fighting distance. From this cannon down to those of 15 centimetres calibre, all current calibres, and lengths of from 30 to 40 calibres, are represented.

The large majority of these cannon are provided with Krupp's "rounded wedge" fermeture. The essential part of this breech-mechanism is the "rounded wedge," which fits in the already described wedge-hole. The wedge is a prismatic block of steel, the back of which is rounded in the shape of a half-cylinder. The forward surface is straight, and at right angles to the gun's axis, while the rear surface, like that of the wedge-hole, is inclined to that axis. When moving in and out, the wedge, guided by slots, moves parallel to the rear surface, and when with the face approaching the front surface of the wedge-hole, and pressed in by the fastening screw, it hermetically closes the breech.

With guns of medium or small calibre, the breech is opened by giving half a turn to the closing crank, thereby relieving the screw, the threads of which are cut away on about one-third of its circumference, and then pulling the crank and the wedge out, until stopped by a stop-screw, at the moment when the bore is laid open. The gun is locked again by an inverse movement.

With larger guns, the weight of the wedge prevents its being pulled out directly by hand. It is consequently provided with a travelling screw, lodged in a recess on the upper surface of the wedge. Let us ourselves try the mechanism of a 30·5-centimetre gun, lying here waiting for the firing test, its breech opened in readiness for projectile and charge. We place the crank on the square end of the travelling screw, and by a few turns drive the protruding wedge home; then we put the same crank on the square end of the closing screw, and by a short turn press the wedge into the wedge-hole. The opening and closing of the monster is quickly done, and the operation lies within the power of a child.

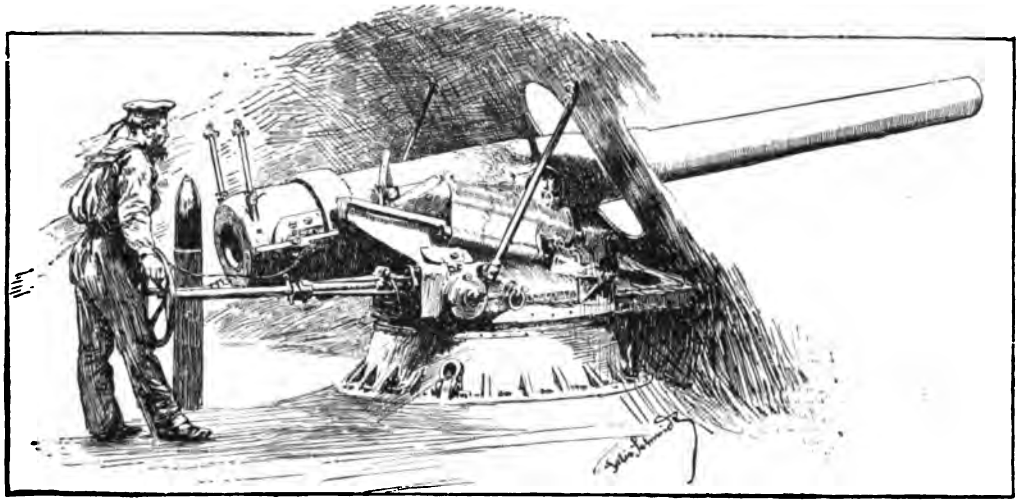
The rounded wedge breech-mechanism can be applied to guns of all calibres. With guns which fire comparatively small charges, and in which the interior pressure is consequently low, a plain wedge, with the cylindrical part omitted, is often used. It is narrower, weighs less, and permits of a shorter breech.

Some of the guns we see in this shop have an "interrupted screw" breech-mechanism. This mechanism is only made to special order, as Krupp himself considers the wedge the better system. With the other fermeture, there is no side opening in the breech, and the bore is closed by a threaded cylinder, screwed in from the rear. In order to avoid the screwing in of the entire length of the cylinder, the threads on it, and also the corresponding threads in the bore, are cut away in three places, so that when the remaining threads on the cylinder face the gaps in the threads of the bore, the cylinder can be pushed in; then turning it for one-sixth of a circle will press the breech-screw home and close the breech. Now to open the breech, the screw is given one-sixth of a turn in the opposite direction; this disengages the threads, and the cylinder is then drawn back. In order to try this ourselves on one of the guns before us, we take hold of the crank attached to the breech, and, by simply turning it, we bring into play an ingenious mechanism which causes the following successive movements; it first turns the breech cylinder one-sixth around, then pulls it back, and by a joint swings it aside, thus clearing the rear opening. When the crank is turned the other way, the same movements in inverted order—swinging, pushing, and turning the cylinder—will close the gun.

With all systems of fermeture the question of obturation is one of great importance. Even if made with the most minute care, it is evident that neither wedge nor screw will hold tight enough to prevent the powder gases, when under high pressure from penetrating and escaping between the breech-mechanism and the adjoining parts of the bore. This escape of gases would be a matter of no consequence were it not for the reason that issuing under high pressure and at a high degree of temperature, they would corrode the metal, causing, where they escaped, erosions which would, after a very few rounds of fire, render both gun and fermeture unfit for use. Therefore, in order to prevent any escape, special appurtenances called obturators or gas-checks are applied.

In Krupp's breech-mechanism the obturator consists of a steel ring of peculiar cross section, set in a hollow at the rear end of the powder chamber, and a steel disc lodged in the front surface of the wedge, facing the obturator ring, and being pressed against it when the breech is closed. As soon as the gun is fired the powder gases press the ring tight against that disc and into the ring seat, so that the contact is absolutely gas-proof. If after long continued use the ring should show signs of erosion, both ring and disc may be quickly removed and replaced by new pieces.

The metallic obturator has also been used with the screw fermeture; but at present the preference is given to an asbestos obturator consisting of a disc half an inch thick, and equal to the powder chamber in diameter, which is saturated with tallow and enclosed between two plates of bronze. This is placed in front of the breech cylinder behind a mushroom-shaped head, which when impelled by the powder gas compresses the asbestos and forces the disc against the inner surface of the gun.



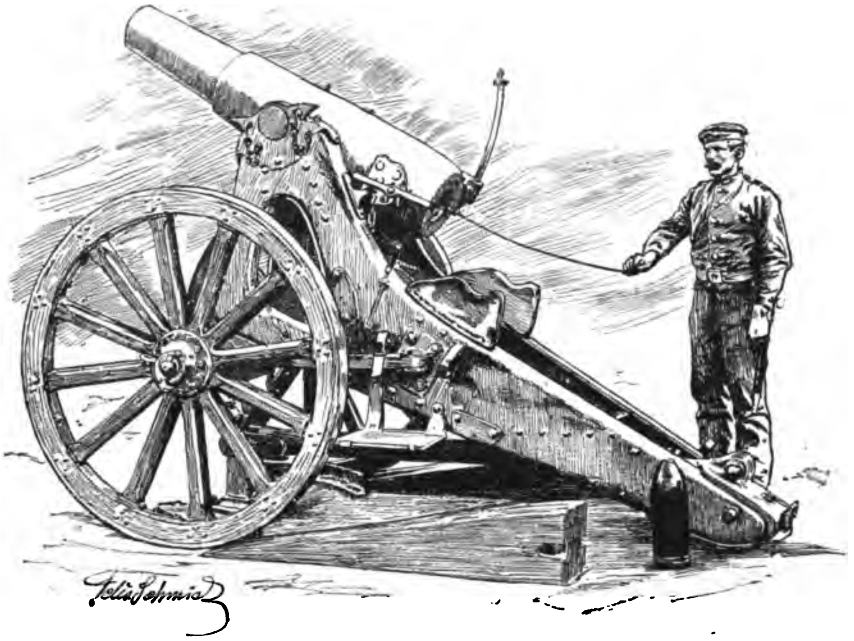
FIFTEEN-CENTIMETRE (6-INCH) QUICK-LOADING GUN L/40 ON NAVAL CARRIAGE

The immense guns which we have examined in gun shop No. 5, are chiefly intended for the main batteries of ironclads and gunboats and for the defence of coasts, and of river and harbour entrances. We now proceed to the finishing shops for smaller guns of 15 centimetres (6 inches) calibre and under. Among hundreds of guns intended for field- and siege-batteries we also find the much discussed rapid-firing, or rather the rapid-loading, guns, the latter name being by Krupp considered more appropriate for certain kinds of them.

The largest rapid-loading guns, of from 12 to 16 centimetres (5 to 6½ inches) calibre, and 40 calibres length, are destined to be used in the main batteries of cruisers and large despatch-boats, also in part of the secondary batteries of armour-clad ships. They can fire from ten to fourteen rounds per minute, while their ballistic capacity is such that, for instance, the armour-piercing shells of the 15-centimetre (6-inch) gun, 40 kilogrammes (88 lbs.) in weight, will at a range of two kilometres (1⅓ miles) perforate 28 centimetres of wrought iron.

The smaller rapid-firing guns are used on all classes of warships. Their great rapidity of fire—forty rounds or more per minute—renders them particularly well suited for fighting torpedo-boats. Thanks to their speed, those small vessels are able to place themselves in a good position for firing their torpedoes within a few moments after coming into sight. During that short space of time much can be accomplished by rapid-firing guns, their peculiar gun-carriages enabling them to aim in quick succession at a number of objects appearing in different directions at varying distances, and in rapid motion. It takes so much longer to load and aim an ordinary gun, that one of them could not fire more than three rounds during the time it takes a torpedo boat to approach from a distance of 1500 metres to 300, while a rapid-firing gun could be discharged more than twenty times.

In addition to the special design of their gun-carriages, which we will later describe, these guns derive their capacity from the manner in which they are loaded, and from certain alterations in the breech-mechanism. The powder charge is not, as with ordinary guns, merely filled into a silken bag, but the cartridge itself is set in a metallic case which is introduced into the powder chamber. This metallic cartridge also serves as a gas check and does away with the obturation ring and disc. For naval guns, the projectile is fastened to the front of the metallic cartridge, just as with small arms ammunition, thus making both loading and firing still more rapid. With ordinary guns, a primer, or a friction tube or a primer screw, must be put into the vent, and exploded either by friction or by percussion in order to ignite the powder charge. In rapid-fire guns the primer, fastened to the bottom of the metallic cartridge-case, is ignited by a firing-pin cased in the breech block, and cocked automatically by the crank when the breech is opened. Its release is effected by pulling either a strap or a trigger. Some of the rapid-firing guns in this shop have a special apparatus by means of which they can, at critical moments, be automatically fired the instant the gun is closed. Such a gun may with justice be called rapid-firing and not merely rapid-loading. After firing, the empty cartridge-case must be thrown out. This is accomplished by the ejector, a lever in front of the wedge with a forked end which, touching the rim of the bottom, embraces the cartridge-case. This lever has at its pivot two short arms against which the wedge strikes when pulled out; thus causing a quick movement of the lever, which throws out the cartridge-case.

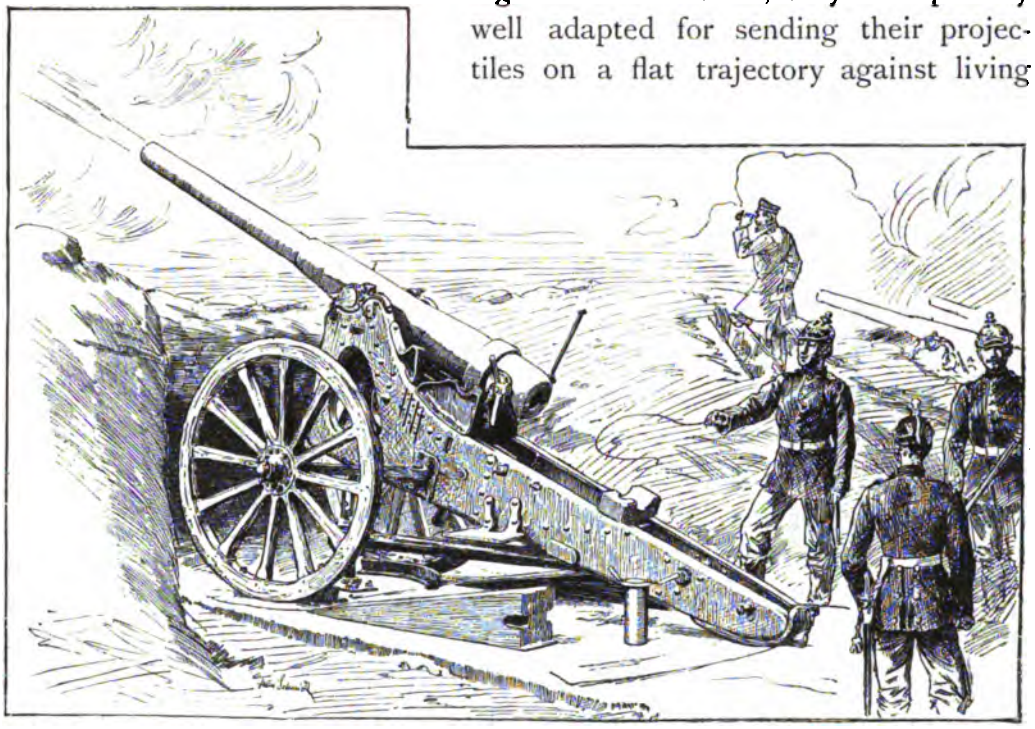


FIFTEEN-CENTIMETRE (6-INCH) HOWITZER ON SIEGE CARRIAGE

We should mention that the efficacy of the rapid-fire guns largely depends on the use of smokeless powder, as the dense smoke coming from the black or brown powders would prevent an immediate re-aiming.

In addition to the use by the different navies of rapid-firing guns, these also hold a place in forts and fortresses, being, for instance, employed in flanking batteries, while their introduction into field- and siege-artillery is probably only a question of time.

The long guns to which we have until now devoted our attention are the only ones which, in the proper sense of the word, are cannon. With their large powder charges, and consequently high initial velocities, they are specially well adapted for sending their projectiles on a flat trajectory against living and against inanimate vertical objects. But in walking through the gun-shops we have also met with some peculiarly short and thick guns. These guns, intended for high curved trajectories, are howitzers of about 12 calibres, and mortars of about 7 calibres length. Although similar smooth-bore guns, often as short as a real mortar, occupied until the beginning of this century quite an important position in maritime and siege artillery, the introduction of rifled cannon seemed entirely to displace them.



TEN-AND-A-HALF-CENTIMETRE (4-INCH) SIEGE-GUN.

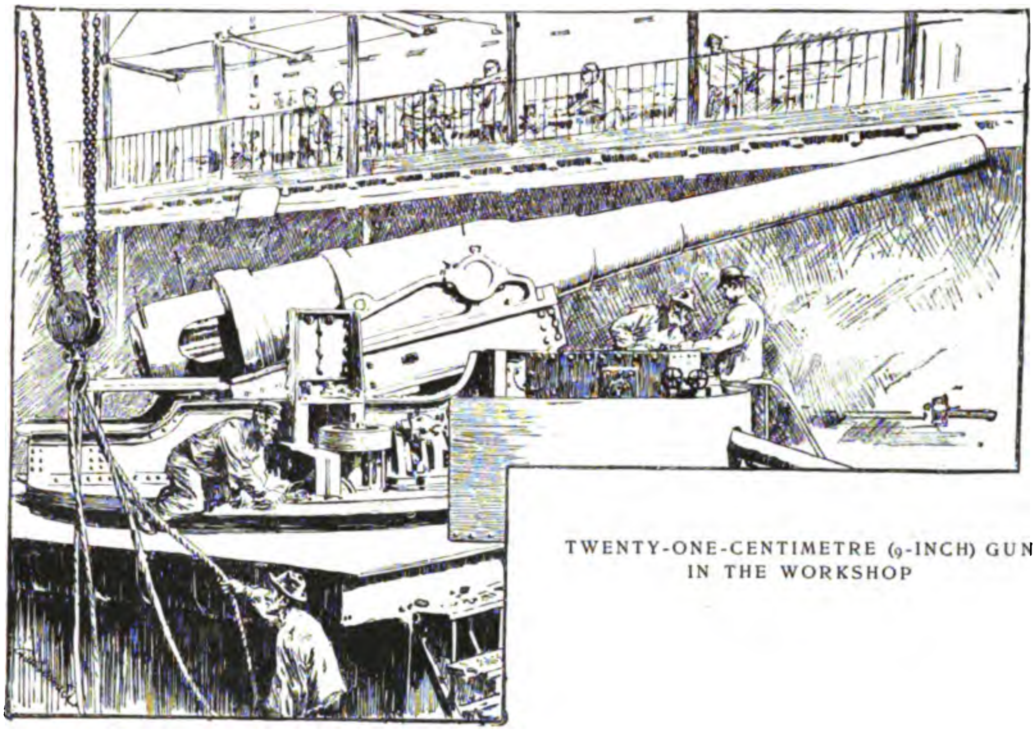
Not until after the Franco-German war did they reappear in modernised designs. The greatest improvement made was in rifling them also, thus making it possible to shoot elongated projectiles on a high trajectory to a range of five miles with great accuracy. And to Krupp, again, belongs the credit of having developed the capacities of this style of gun, and of having brought it to its present perfection. The Krupp factory turns out howitzers and mortars from 7·5 to 35·5 and even 40 centimetres (3 inches to 14 and 16 inches) bore; and a number of governments, convinced of their efficiency, use these guns in their armies.

With relatively small charges and high elevation (up to 65 degrees) they preferredly fire projectiles carrying large and most effective bursting charges. The trajectories are very much curved, and the projectiles strike almost vertically.

It is particularly this latter circumstance which enables these guns to hit their aims behind frontal protections, and to bombard horizontal coverings, such as "bomb-proof vaults" and armour turrets, which by a flat trajectory can only be hit at very acute angles. The purposes therefore, for which they are best suited, are those of siege and defence. Recently, however, howitzers and mortars have also been mounted in coast batteries, being designed to pierce the armoured decks of ironclads, thus reaching powder magazines and boiler-rooms, the so-called vital parts of a ship, which are protected by very heavy armour against horizontal fire.

In a short space of time we have witnessed, from the casting of the steel block to the reception of the completed piece, all the processes gone through in making a gun. In point of fact, however, it takes two years, and for the largest among them, an even longer period to finish one. Upon its careful manufacture depends its range, perforating power and accuracy. And then to complete it and make it a serviceable weapon it must be mounted on a gun carriage.

The great number of different styles of guns, various as to size and purpose, have naturally called forth almost innumerable styles of mounts and carriages. In the open field, for instance, the demand is for the greatest possible mobility; that is to say, the mount, on wheels, must be light and simple, in order that the position of the guns may be quickly and easily changed; it must also be fitted for long marches, and must permit of a rapid alteration from the marching to the firing condition. For siege and fort guns, while a certain facility for transport must not be neglected, the mobility of the mount is much less important, the chief requirements for which this must be fitted being those of permitting the gun to be fired from a covered position, and of checking its recoil as much as possible. Coast guns and naval guns being stationary in their places, facility for transport is of no importance for their mounts, which must, however, for the naval guns, be of the smallest possible weight.



TWENTY-ONE-CENTIMETRE (9-INCH) GUN IN THE WORKSHOP

A great diversity also exists in the aiming apparatus, ranging from the simple elevating screw of a field-gun to the complicated mechanisms of rapid-firing and naval guns.

All these different constructions are found in Krupp's workshops in varying stages of completion. We can only give a glance at the principal types.

In the military vehicle shops we meet with the two-wheeled field-gun carriage. This consists of two cheeks of steel plate, flanged all round and converging towards the rear, held asunder by transoms; their forward parts rest on a steel axle which is supported by two wooden wheels. The rear end or trail rests on the ground. The trunnions of the gun rest in two casings above the axle and its breech on the elevating screw, the nut of which is fixed in a transom. Turning the screw will lift or lower the muzzle of the gun. A change of direction, or traversing the gun, is generally effected by moving the trail of the carriage. A brake which stops the wheels in order to check the recoil serves also as a driving brake. It may be mentioned that several new designs of brakes intended to check or to suppress the recoil of field-guns are now being tried.

The mounts for siege-guns are constructed on similar principles, but are usually placed on a platform. To this platform a pivot is bolted, on which hangs a hydraulic brake which limits the gun's recoil. Recoil wedges placed behind the wheels cause the gun after firing to run again into battery—*i.e.*, into firing position.

In another shop we see being manufactured the more complicated carriages for quick-firing naval guns. These have, bolted to the deck, a cylindrical stand or pivot-block, which acts as a turn-table for the carriage. Friction in turning is reduced to a minimum by a circle of polished steel balls on which the pivot-plate revolves. The turn-table carries a chassis with inclined slides on which the carriage proper runs in and out, this top carriage being furnished with bearings wherein to carry the trunnions of the gun. Hydraulic brakes attached to the sides of the top carriage reduce the recoil to a few inches, and the inclination of the chassis makes the gun slide forward into battery again after recoiling. Changes in elevation and in direction are made by the aid of handwheels and worm gearing. The sighting apparatus is on the same side of the gun as the handwheels, so that a gunner handles the direction and the elevation wheels simultaneously. In order to protect the gunners the carriage is provided with a shield of steel plate.

In addition to these fine constructions, working with surprising accuracy, we see here, in course of manufacture, some other designs of carriages intended for rapid-firing guns. Among these, our attention is especially attracted by the so-called "cradle" gun-carriage. At the first glance it appears to be quite similar to the one just described, and with regard to the pivoting, its design is, in fact, identical. But we notice that where we are accustomed to see the trunnions, the gun is enclosed in a bronze jacket, having trunnions which lie in bearings on the carriage. While the gun fits very exactly in the jacket, it can move in the direction of its axis. Therefore, in recoiling, the gun moves backward without changing the position of its axis, and without moving the jacket or the aiming apparatus which is affixed to it. The length of recoil is reduced by a hydraulic brake, of which the piston is, by a strong arm, attached to the gun. The return movement is effected by means of a spring. The apparatuses for elevation and direction are similar to those of the carriage previously mentioned.

In order to inspect the carriages of the biggest guns, we enter one of the largest and finest among Krupp's workshops. This is 75 metres in length by 40 metres in width (246 feet by 131 feet), and has a gallery running all round it, which provides space for the less bulky kinds of work, while its wide hall is spanned by two travelling cranes of 75 tons capacity each. Below these cranes we see, in various stages of completion, the immense gun-mounts. In principle, these are closely related to the carriages already described. They have a chassis, a top carriage, and hydraulic recoil brakes. The main difference is found in the revolving apparatus. We remark that this is mounted on a turn-table, sometimes having an armour cupola, sometimes without one, which, as with the rapid-fire gun-carriages, can be turned round to any desired point. Instead of being loaded, elevated, and revolved by simple mechanisms operated by hand, heavy guns are served by ingenious machinery which performs all these functions. A small steam-engine placed in a secure position near the gun, furnishes the power which is transmitted, usually by hydraulic force, to the gun-carriage. We have already observed this admirable system in operation at the forging presses, and here, also, we again see that one man handling the levers of the different valves, can produce all the movements, both main and secondary. Transferring the power by electricity, has, with complete success, latterly been practised with these carriages.

There is no better way to finish our inspection of the sinews of war than by a visit to the very interesting museum attached to Krupp's factory. There we shall find a fine collection of the different styles of guns, projectiles, &c., which have been, during the last forty years, manufactured at Essen. Amongst other models stands a very carefully made one, of a rotating turret for two guns. It works by hydraulic force, and shows how, by that power, the fermeture is opened, the ammunition hoisted from below and by hydraulic rammers driven into the chambers of the guns. Then the loaded guns are closed and brought into firing position ; they may then be either elevated or lowered, and the whole turret may be turned to the right or to the left.

CHAPTER XVII

PROJECTILES AND POWDER-CHARGES

THE gun is a motor which develops the latent energy of gunpowder. The projectile is the recipient and the transmitter of this energy. Its dead mass receives, as an equivalent of the energy of the powder, a distinct velocity, and consequently the faculty of demolishing obstacles, or in other words of reproducing its energy.

LATHE IN THE FUSE SHOP

But an artillery projectile is not merely a mass endowed with a certain energy. In addition to its power of perforation, it adds a new and independent element to the action of a gunshot, by being itself the bearer of a bursting charge. This charge breaks the projectile into a number of small pieces, each one of which has on living objects the effect of a bullet. In siege and naval warfare, the explosive force of heavy shell, in addition to its direct action, is also indirectly efficient by means of flame, smoke and asphyxiating gases. Finally the flame produced by the explosion of a shell discloses the position of the enemy and enables the gunners to determine the previously unknown range.

Thus the shell is revealed to us as an instrument fitted to many uses. Our interest in learning about it is increased by the circumstance that in the history of the improvements which have been made in its construction, the great factory we are examining occupies an important place, and has always been one of its largest wholesale manufacturers.

Excepting the canister or case shot, which corresponds to the small shot of a shot gun, in all projectiles the longitudinal section is shaped like a gothic church window, while near the rear end is a copper band, generally grooved, and larger in diameter than the cylindrical shaft of the projectile. When the gun is fired the soft metal of the band is pressed into the rifling, and thus performs the double function of centring or guiding the projectile, and of preventing any escape of gas beside it.

Let us first give our attention to that projectile, of which the production is justly considered one of the greatest triumphs of modern metallurgy, viz., the steel armour-piercing shell. Quite simple in design, with a solid point, and a relatively small cavity, closed at the bottom by a threaded plug, it must be made out of a material which unites the highest physical qualities; for it is designed to perforate plates of iron and of steel up to a foot or more in thickness. The enormous resistance of such plates can only be overcome by iron carbon alloys, artificially hardened, and to prevent any upsetting of the impinging projectile, having an elastic limit of not far from 100 kilogrammes per square millimetre—*i.e.*, 140,000 lbs per square inch. In order to pierce the hard surface of modern ship armour, or destroy the chilled iron protection of coast batteries, the point of these projectiles must be of the greatest possible hardness. And yet in spite of its tempering the material of the projectile must still retain a certain toughness, in default of which it would shatter on impact without producing a sufficient effect.

In Chapter II. the writer has already mentioned the fact that early in the seventies Krupp began to manufacture heavy armour-piercing steel shell. Made with as much care as the finest tools, machined, tempered and annealed, these projectiles so favourably unite strength, hardness and toughness, that neither compound nor hardened steel armour plates on ships or turrets can long resist them, They are forged from good sized blocks of crucible steel of a special composition, and are very accurately finished in the projectile machine shop. The chief difficulty to be overcome lies in the hardening, and is, as every blacksmith knows, one which increases in proportion to the size of the object treated. So that when armour-piercing shell are spoken of as being a remarkable production, allusion is made to those intended for heavy guns of, say, from the 21-centimetre (8-inch) calibre upwards. The details of their fabrication—*i.e.*, the methods of refining, tempering, and annealing them—are kept secret.

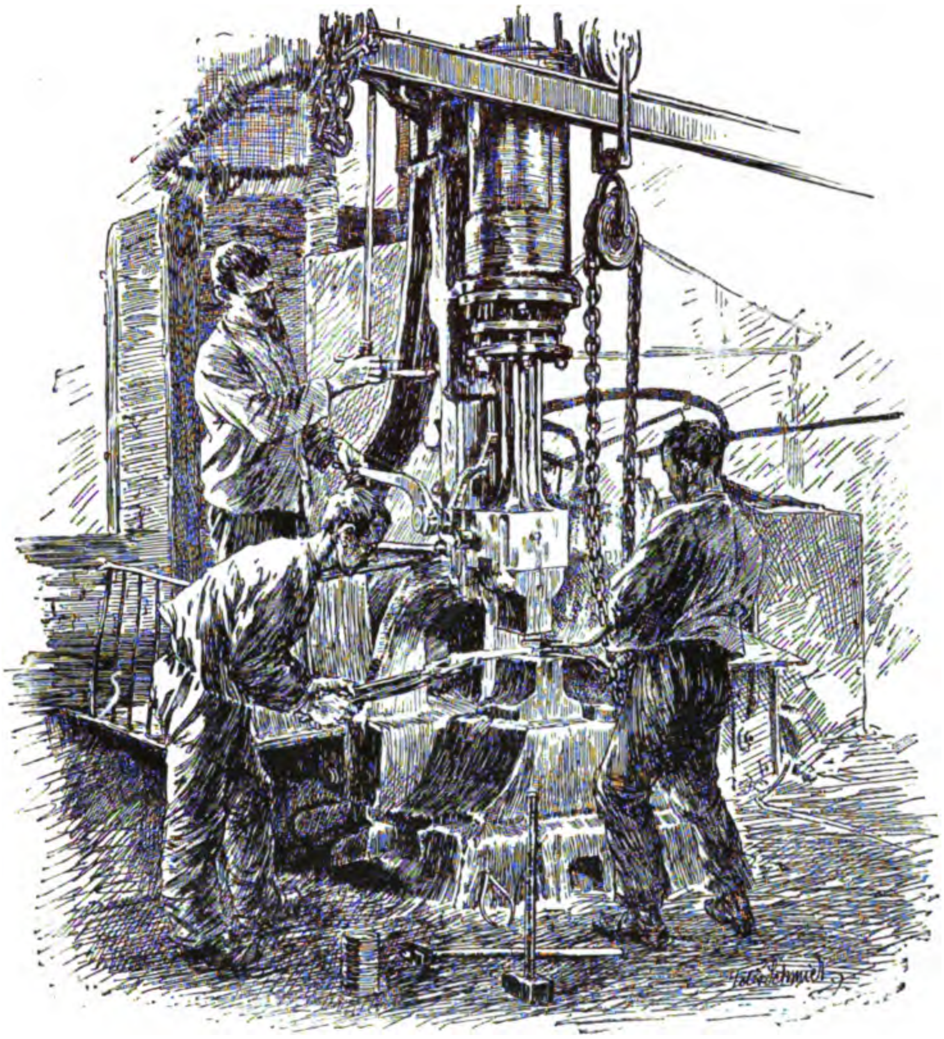
A HIT FROM THE TWENTY-FOUR-CENTIMETRE (10-INCH) GUN

A few lines must be devoted to the chilled cast-iron shell, although it can no longer be considered an armour-piercing one. Its material is a special mixture of cast-iron. When this is cast into thick-walled iron moulds, as a consequence of quick cooling its exterior layer becomes a hard white alloy of carbon and iron an inch thick, while towards the interior the mass gradually changes into gray iron. The bottom of a mould intended for a chilled iron shell is made of cast-iron, the hollow for the ogival point of the shell being smooth turned, while for the cylindrical shaft, the rest of the mould is, in the usual way, made of moulding sand. The projectile issuing from such a mould has a strong, tough, cast-iron body and a head on which the skin is as hard as quartz. These chilled cast-iron shell are cheap, but nowadays are only used to attack comparatively thin armour of soft iron, such as is still carried by many of the older men-of-war. Their wholesale manufacture is one of the specialities of the well-known Grusonwerk, near Magdeburg, which was a few years ago annexed to Krupp's kingdom.

While armour-piercing shell are intended to be effective, chiefly from their perforating power, some of them are, however, provided with a bursting charge, which in, for instance, a 30·5-centimetre (12-inch) shell amounts to 5 kilogrammes (11 lbs.). They have no fuse, as ignition results from impact on armour or any heavy iron construction.

Whilst with regard to aims of this description, armour-piercing shell are the only efficient projectiles, when directed against thin armour, wooden or brick walls, or against troops in the open field, their effect does not exceed that of a solid shot of equal calibre. For such aims hollow projectiles with fuses are preferred, among which shall be first mentioned common cast-iron shell having a bursting charge and percussion fuse. The fuse is screwed into the head of the projectile, and at the proper moment causes the ignition of the bursting charge. This charge, which until recently always consisted of black powder, has now been successfully made of high explosives, with the result that part of the splinters are projected not only at right angles to the trajectory, but even backward and with sufficient force to enable them to reach aims protected by covering walls or parapets.

Every shell is provided with a percussion fuse containing a primer and firing-pin. The latter is, by a strong brass spring, held in such a position as to render ignition of the charge before firing an impossibility. But as soon as the shell is fired the firing-pin is released by the spring, and can slide freely backward and forward in the interior of the fuse. When the shell encounters an obstacle, the pin by its inertia is driven forward into the primer, and in less than one-hundredth of a second the shell bursts. In the open field, a shell, in order to produce its intended effect, should reach the ground a little short of its aim, should rise again, continue its way for a few yards, and then explode, sending out a conical sheaf of particles which spread widely and act as so many separate projectiles. Of course, if ramparts, walls or buildings are to be attacked, the projectiles are aimed directly at them, and burst either in, or else immediately behind them. In naval artillery the percussion shell has preserved its former importance; for although a modern man-of-war is called an armour clad it is, in point of fact, with the



STEAM-HAMMER IN THE PROJECTILE FORGE

exception of its so-called vital parts, almost devoid of protection against artillery fire, and it is difficult to picture the damage which a large percussion shell exploding between decks may do by its great bursting charge, which projects heavy pieces of iron in all directions. Perhaps future events in naval warfare may prove the opinions of those persons correct who maintain that at present, as well as in the days of Trafalgar, victory will in the main be due to the use of the common shell.

Combined with the percussion-fuse, we find in some bursting charges a time-fuse of much more complicated construction. This fuse also explodes a shell during its flight at the expiration of a certain number of seconds, the exact time being beforehand determined by varying the length of a column of compressed powder. It is superfluous, and indeed hardly possible in few words, to explain the detail of these very ingenious double-action fuses, of which thousands are in great perfection manufactured in Krupp's workshops.

TURNING LATHES FOR PROJECTILES

For some special conditions arising in siege and naval warfare, projectiles with particularly large bursting charges are desirable. On account of the enlargement of the cavity, the walls become so much thinner that cast-iron is not sufficiently resistant. Therefore, the proper material for these projectiles is steel, especially for the so-called "mining shell" of six calibres length, used in high angle fire.

The shrapnel, which is always provided with a time- or a double-action fuse, is outwardly quite similar to the shell, but its filling consists of small balls of hardened lead or zinc. When it strikes the ground before bursting, its action is the same as that of a shell. Used against troops in the open field or under cover it is most efficient, when as the result of a correct adjustment of the aiming sight and the time-fuse, it bursts in the air in front of and at about 50 metres (54 yards) distant from the aim, sending obliquely from above a shower of balls and splinters, which covers a large space. Heavy naval ordnance also is provided with shrapnel. Those destined for the 30·5-centimetre (12-inch) gun contain 1500 balls of 100 grammes (3½ oz.) each. They are intended to sweep the decks and destroy the rigging of hostile ships.

ASSEMBLING FUSES

Of the manufacture of cast-iron projectiles in Krupp's factory we have already spoken in Chapter XIV.

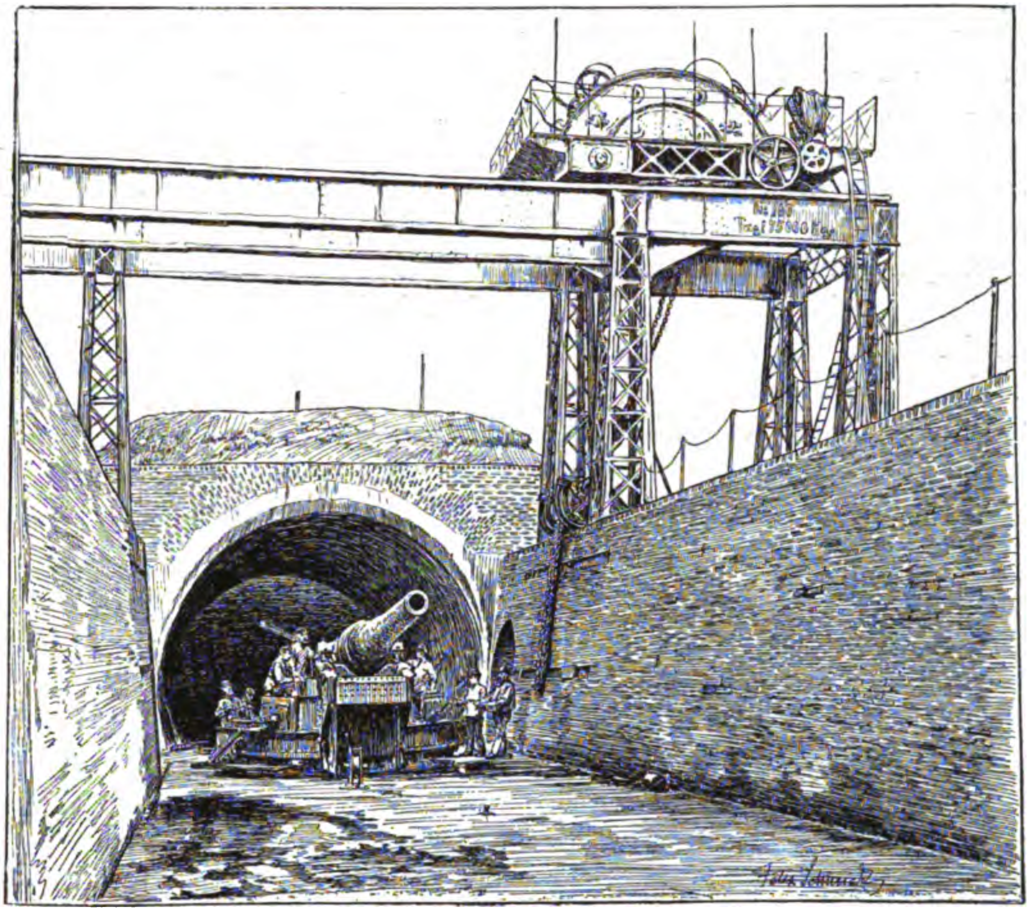
The steel bodies of the shrapnel shell and mining shell are in the rough mostly produced in a special forging-shop situated next to the great gun-carriage works. Ingots of medium open-hearth steel are forged into bars of the approximate diameter of the projectile and are then cut into short cylinders. These cylinders are put into moulds and are forged by steel hammers into a shape resembling that of a crucible. Then after being re-heated they are pressed by a steel punch into a steel matrix. Finally, the upper rim of these hollow tubes is, by special machinery, converted into the bottom of the projectile.

The exterior machining of the projectiles, the turning them true, adding the copper band, threading the shell and shrapnel to receive the fuse, and the armour-piercing shell to receive the breech-plug, is done in the projectile lathe shop, a capacious four-storey building 160 metres (500 feet) deep, which stands near the Limbeck Road.

ENGRAVERS' ROOM

We shall find a walk through the fuse shop next to the forge extremely interesting. In spacious rooms, hundreds of almost automatic special tools may be seen used for manufacturing the many small parts composing the different kinds of fuses out of bars of bronze or brass, cutting them as quickly and easily as if cutting wood. The sub-division of labour is perfect in this machinery. In the store-room great heaps of the various parts are piled on numbered shelves.

The uniting of the pieces forming the fuses together with the addition of the compressed powder columns and primers, is done in special laboratories. It is well worth our while to visit the laboratory situated near the northern end of the turnery for railway wheels and axles, where the double-action fuses are finished and the powder is pressed into the ring-shaped groove of their timing pieces. In order to ascertain whether the time required for the



VAULT AT THE ESSEN SHOOTING RANGE

combustion of the powder circle corresponds with that marked on the head of the fuse, the accuracy of the timing is constantly tested by a pendulum chronometer.

As we issue from this shop, which lies near the border-line of the great factory, we overlook a valley set with willows and poplars; on the summit of the green slope, rising on its further side, stands a pretty house surrounded by glowing beds of flowers. A remnant of peaceful nature seems there to have found an asylum. But while we admire it a loud report resounds, the ground trembles, and the little hill on our right appears to have been transformed to a volcano belching forth smoke and a shower of stones. So after all it seems that this is far from being a restful quiet nook. It is on the contrary a shooting-range, where the metal mouths of the new-born guns pronounce their first words. The hill hides in its bosom the emplacement for the guns, built of huge blocks of stone; while above this is a bridge with a railway track. A crane of 150 tons capacity lowers the guns and carriages to their stand. A cut in the hill and a tunnel of 50 metres (54 yards) length forms the range.

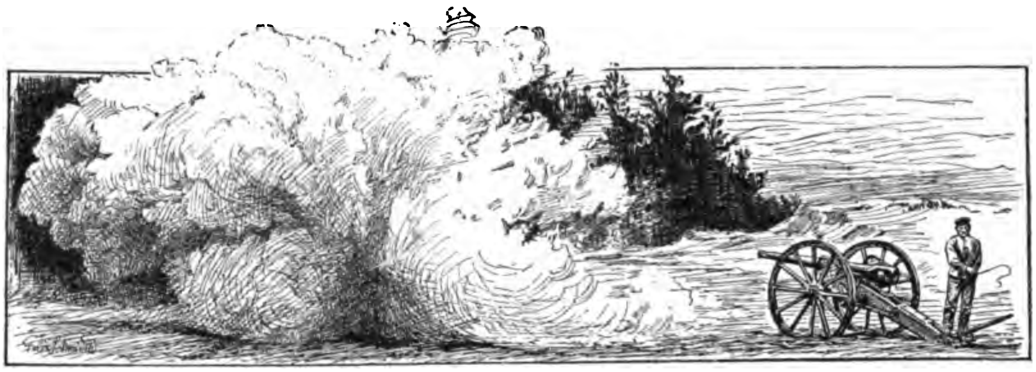
We are given to understand that this is not a shooting-ground for artillery, but merely a very large and costly testing-place for the gun-shops. Here, by a number of rounds, only the resistance and working of the mechanisms of the finished guns and carriages are tested. It is also here ascertained whether the ballistic capacities of the guns are satisfactory.

We repair to the little house seen from a distance, and there find its chief engineer busy among measuring instruments, graphic and numeric tables. But before obtaining any information concerning all the interesting apparatus we see, and the methods for measuring gas pressures and velocities, we must try to learn something about that substance in which lies dormant the terrific force a gun arouses.

With the close of our century, also ends the reign of the antiquated black mixture of nitre, charcoal and sulphur; after six centuries it must now, at this period of transition to a new epoch of civilisation, yield its place to explosives of a new and totally different kind. The attention of ordnance officers was long since drawn to nitrated organic matter, especially to gun-cotton and to nitro-glycerine, which from their great explosive power had already been found to be most valuable for blasting rocks, piercing tunnels, &c. These substances contain the most active elements of saltpetre, oxygen and nitrogen in an unstable combination being not a mechanical mixture but a chemical composition. In exploding, the oxygen frees itself from the nitrogen, and combines with carbon and hydrogen into gaseous products of combustion. Thus the whole substance is converted into invisible gas and vapour. One gramme of gun-cotton pressed into tablets furnishes a quantity of gas which at freezing temperature forms a volume of not less than 900 cubic centimetres. But as the explosion also yields 1000 units of heat, which raises the temperature of the gas to 3000° R. (6800° F.), the gas extends its volume to 10,000 cubic centimetres; or in English measure 1 ounce of gun-cotton powder delivers 0·9 cubic feet of gas at freezing temperature, or 10 cubic feet at 6800° F. This enormous expansion, and the corresponding gas pressure which rises up to 15,000 atmospheres or 220,000 pounds per square inch, has not only been calculated but has been actually measured. In exploding nitro-glycerine the quantity of gas produced is about the same, but the heat of explosion is 50 per cent. higher. It is in fact the most powerful of all known explosive substances. In comparison with it gunpowder, which produces 270 cubic centimetres of gas and 725 units of heat, seems weak indeed. Gunpowder has also the disqualification of leaving, after exploding, more than half its substance in a solid state, partly in the form of thick disagreeable smoke and partly as a residue in the bore of the gun, where it is apt to interfere with the correct movement of the projectile. Indeed, the only advantage to be gained by the use of gunpowder lies in the fact that it is considerably cheaper than its new rivals.

Gun-cotton and nitro-glycerine, like most similar compounds, possess a faculty which is detrimental to ballistic effect, namely, the one of detonation; that is to say, of changing, in accordance with the chemical laws mentioned above, instantaneously into gas when exposed to sudden pressure. The gaseous particles are then projected with such violence that where they strike they shatter rocks and even steel. It is a well-known fact that a dynamite cartridge, exploded by an attached primer cap, will, if in close contact with a steel rail, break it. If it detonated in the powder chamber of a gun it would certainly ruin the interior layer of metal, and might even burst the gun.

Only about ten years ago was it discovered how, by special additions and proceedings, gun-cotton could be produced without this detonating faculty. And it is really remarkable that now the most highly esteemed modern gunpowders consist of gun-cotton and nitro-glycerine, with no other additions excepting very small quantities of solid hydro-carbons. These gunpowders have been tried for years on the proving-grounds, and could in no way be detonated. All these modern powders, whether they consist almost entirely of gun-cotton, or whether they contain a greater or a less quantity of nitro-glycerine, always appear as either gray or brown horn-like matter. For, small-arms as well as for cannon they are made into cubes or tablets, which increase in size according to the calibres of the arms for which they are destined. Some are also manufactured in the shape of flats and cords, and one of the newest kinds is known as macaroni powder, thus named because it consists of little tubes, the length of the powder chamber, the diameter of which varies from that of ordinary macaroni to the size of the bean-shooters used by boys. A round fagot of these, made of a size to fill the chamber exactly, is put into the powder bag, the bottom of which holds a thin layer of fine black powder, intended to ignite in one moment the whole length of the tubes.



SHOOTING WITH BLACK POWDER

When lighted in the open air all these modern powders burn remarkably slowly and quite harmlessly. But shut up in the chamber of a gun, owing to the enormous gas pressure developed, the explosion is accomplished with almost incredible rapidity, sometimes in less than a hundredth of a second, of course more quickly with fine grain than with coarse grain powders. Here we touch upon a very important question, viz., the time certain powders occupy for their combustion in a gun. It is evident that if the powders we have been discussing detonated or burned as quickly as common sporting powder the explosion would be completed before the heavy shell of a cannon had made any length of way. Thus the powder gases behind the projectile, compressed into the small volume of the chamber, would produce a pressure of 6000 or more atmospheres. And not until then would the projectile, by their expansion, be driven from the bore. One such round would probably suffice to make the gun unserviceable, not so much from the abnormal pressure as from the dynamic effect of the gas particles projected with almost inconceivable quickness against the walls of the chamber. Gas at high tension and high temperature will erode the hardest substances, as does a sand-blower. The erosions, mentioned in the preceding chapter as being caused by the minutest leakage of powder gas, are a proof of this. Therefore combustion must be retarded in order to give the projectile time to move forward before the maximum admissible pressure of from 2500 to 3000 atmospheres (34,000 to 44,000 lbs. per square inch) is reached. The chief means taken to fulfil this end is making the powder into coarse grains. For heavy ordnance the black powder is pressed into short hexagonal prisms of 50 grammes (about 1·8 oz.) weight. Yet even so the explosion is very rapid, and in the largest guns, with the coarsest grains of powder, does not take longer than a hundredth of a second. It ends when the projectile has advanced so far that the free space left behind it is

SHOOTING WITH SMOKELESS POWDER

about double the volume of the chamber. From that instant the gas only expands, and its pressure rapidly diminishes. The longitudinal section of the gun, thickest over the chamber and sloping thinner towards the muzzle, gives a fair idea of the pressure diagram.

From what precedes it is evident that without an exact knowledge of the gas pressures it is impossible to construct a gun properly. Consequently, the determination of these pressures is the chief task at the Essen factory shooting range. Apparatus and methods which are comparatively simple have been invented for this purpose, so that petty overseers are able to measure those enormous pressures with ease and accuracy. One of the most interesting apparatus is the crusher-gauge, which can without special preparation be used in any gun. It consists of a small cylindrical box of steel plated with copper, 6 centimetres in length and 3 centimetres in diameter (2·4 inches by 1·2); its cover is screwed on, and through the cover reaches a short steel piston 11·1 millimetres (0·437 inch) in diameter. In the box is a copper cylinder of 10 millimetres (0·394 inch) diameter and 15 millimetres (0·519 inch) in length, centred by a rubber ring, against which the piston, packed in tallow, is pressed. This little apparatus is put into the cartridge near the bottom; after the gun has been fired it remains in the chamber. It is evident that during explosion the gas will press the piston towards the copper cylinder, and thus compress it. When the box is opened the upsetting of the cylinder is measured by a micrometer and the pressure is ascertained.

The copper cylinders required for the crusher apparatus must be manufactured with extraordinary care. From each delivery of copper a number of cylinders are turned, and are then, in a special lever press, exposed to increasing pressures, the corresponding shortenings being measured and tabulated. Between the limits of 2000 and 3000 kilogrammes total pressure, a shortening of 0·1 millimetre corresponds to an increase of pressure of 60 kilogrammes per square millimetre, or to an equal number of atmospheres. (In English measure: between 29,000 and 44,000 lbs. per square inch, a shortening of 0·004 inch means an increase of 875 lbs.) Therefore, at the shooting range, after measuring the cylinders compressed by the experiments, the corresponding pressure can at once be learned from the table. In order to make the tests still more accurate, all the copper cylinders receive a preliminary pressure of 1000, 1500, 2000, &c.,

atmospheres ; and in the chambers cylinders are placed, of which the first pressure approaches that expected in the test.

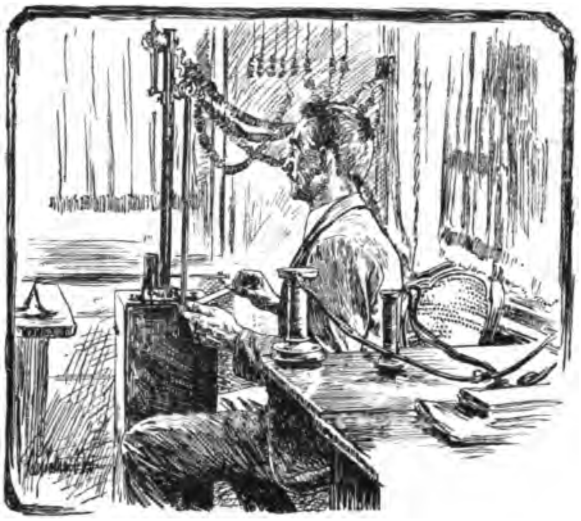
With experimental guns, used on the proving-ground for ballistic studies, the crusher is either set in the obturator plate, or else this plate is merely perforated for the crusher piston, while the copper cylinder is lodged in the closing wedge.

Such guns are provided with a second pressure-gauge, named after its inventor—the Rodman. This also is in the form of a piston, but has on it a chisel, the edge of which is ground according to a certain fixed rule. This chisel, under pressure, cuts on a copper plate a mark, of which the length and depth depend upon the amount of pressure. Thus, by measuring the length of this mark, the pressure is determined.

While these measurings show what strains the cannon and its breech are to withstand, they also indicate the force with which the projectile, in the beginning of its course, is driven forward. By taking into account the weight and chemical composition of the powder charge, it is possible, in accordance with well-known mechanical laws, to calculate the decrease in pressure of the expanding gas up to the instant when the shell leaves the bore. The area of the pressure diagram represents the mechanical work done by the gas, which work is transformed into the energy of the projectile. The relation between this energy and the total weight of the gun and carriage is of great practical importance. In general, that gun is preferred which, with the least total weight, will produce the greatest energy in its projectile. The exceptions to this rule are guns intended for certain special purposes.

The energy of a projectile is, as we know, proportionate to its weight and the square of its initial velocity ; the velocimeter, a measurer of this velocity, being another very important apparatus, used at the shooting range.

High velocities are determined by measuring very brief times ; for instance, the time a projectile takes to cover a short distance of 50 metres (164 feet) at most. Among many methods of measuring these brief times, that invented by Le Boulengé is the one most used on the proving-grounds. With his apparatus time is measured by observation of the space traversed by a falling weight. It has two electro-magnets with downward pointing poles to which two iron bars continue to hang as long as the two currents are closed. One of these currents passes through a copper wire, which is led to and fro across a wooden frame placed near the muzzle of the gun; the second current passes through a similar wire led in the same manner across another frame placed 50 metres in advance of the first one. When the gun is fired the projectile goes through both frames and breaks one current after the other. The two iron rods will fall the instant their respective currents are interrupted. One of the rods, the shorter and the last to drop, strikes a small steel plate, thus causing a small cutter to hit and to mark the other longer rod which fell first. Then the distance of this mark from a zero mark made beforehand is measured, and by that distance the difference in time between the first fall and the second is determined. A difference of, for instance, one-tenth of a second, with 500 metre-seconds velocity, would correspond to a difference of 49 millimetres of fall—*i.e.*, 1640 foot-seconds to 1·93 inches. The zero mark is obtained by sending one current through both magnets and then interrupting; which, of course, makes both rods drop simultaneously. It may be added that the longer rod has a covering of zinc plate which receives the marks and which can, at will, be exchanged. By means of this simple and easily understood apparatus,



LE BOULENGÉ CHRONOSCOPE

any technical assistant can learn to determine velocities of projectiles at any distance from the muzzle of the gun with an accuracy down to 1 metre. When we visit Krupp's proving-ground we shall see how quickly and how easily this work is done.

In this, as in most other chronoscopic apparatus, the part played by electricity consists in directly or indirectly fixing those moments which limit the time to be measured, by two marks as little as possible distant from each other, made on an organic part in regular movement. With some more complicated apparatus this is done on a uniformly rotating roller, the axle of which is threaded in order to give the roller an axial movement. The marks caused by closing or interrupting currents appear on the surface of the roller, and the length of spiral between them gives the measure for the brief interval of time.

We cannot here describe in detail these finer chronoscopes, which are certainly not well fitted for the running practice of the proving-ground. They may, however, in the hands of skilled and experienced physicists, lead to important discoveries. Even one hundred-thousandth of a second can be determined by them, which makes it possible to record the movement of a projectile inside the bore of a gun. For this purpose the experimental gun is given a number of fine lateral perforations between the chamber and the muzzle, in which electrical currents are inserted. The projectile when fired destroys these contacts one by one; in that way causing the markings on the chronoscope of which mention has been made; and affording a fairly accurate representation of the gradual increase of velocity.

From the diagram of velocity may also be deduced the gas pressures, the theoretical and practical importance of which has been previously mentioned.

LAYING A FIELD GUN

CHAPTER XVIII

KRUPP'S PROVING-GROUND NEAR MEPPEN

It would scarcely have been possible generally to introduce Krupp's guns so rapidly had the task of testing them been solely entrusted to the ordnance officers of the different governments. Alfred Krupp, however, with his usual foresight and energy, in order to develop his ideas on the basis of practical experience and to meet the world with established facts, instituted his own proving-grounds.

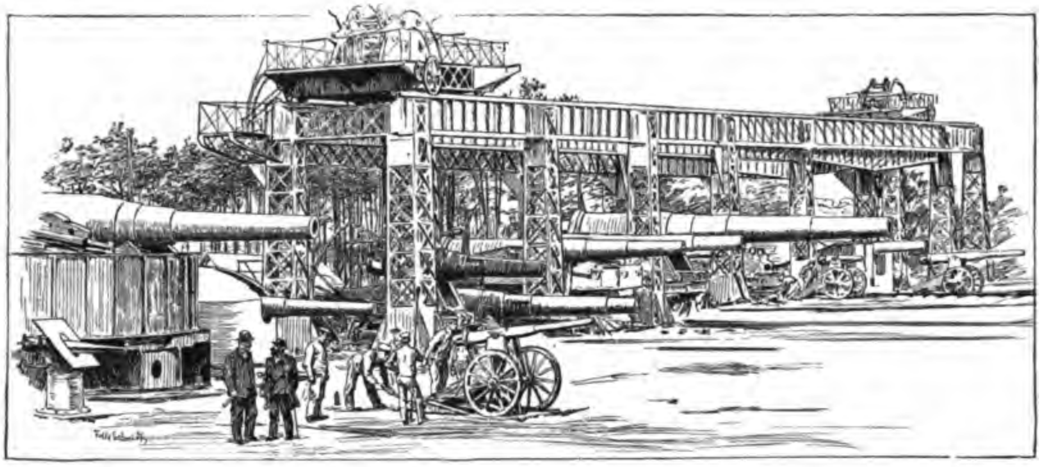
As early as in 1873 he founded near Dülmen in Westphalia his first proving-ground, which had a shooting range of 6200 metres (nearly 7000 yards), but because of the increased efficiency of modern guns only a few years later this became inadequate. Consequently, in 1877, Krupp obtained, partly by purchase and partly on a lease, an almost level stretch of land more than fifteen miles in length, and there established a proving-ground for ordnance experiments of every description. Up to the present time no government nor any private establishment can boast of a proving-ground which equals this one, where experiments on a large scale, which have acquired an international importance and reputation, are from time to time made, in the presence of crowned heads, as well as in that of officers from European and other countries. And the activity of the Meppen proving-ground is so closely connected with the development of the Essen steel factory, that one chapter of this book may most appropriately be devoted to a description of it.

It was on the day after Christmas that the writer started for that chosen land, which, for some reason to him unknown, is among the initiated called "Muffrika." When, after a fatiguing journey of twelve hours, he left the train, it was to find at the station, waiting to receive the guest, who at this quiet holiday season had come to disturb the silence of the place, a servant from Krupp's boarding house. And that is a hospitable abode of which the comforts can scarcely be exaggerated. The writer had just made himself at home in one of its fourteen large, well equipped bedrooms, when he was summoned to an excellent supper in the dining-room. He was the only guest and found himself, so to say, master of the house, which is not in the ordinary sense of the word an hotel, for its inmates are received and treated as Mr. Krupp's invited guests. In the evening the commandant of the shooting ground, a portly gentleman in the prime of life, whose carriage and demeanour clearly betrayed the former officer, came to welcome and to keep him company for an hour. As the writer was anxious to make the best use of his time and to assimilate as much scientific matter as possible, he asked many questions, and a deep dive into the mysterious laws of the flight of projectiles was taken. Afterwards, so deeply interested was he, sleep refused to visit him; the midnight hour found him still poring over the famous blue booklet containing Krupp's tables for the calculation of trajectories; and not until long afterwards did the function of the resistance of air fade into the imaginary and indefinite.

At dawn the captain came to conduct the writer to the proving-ground. A normal gauge railroad, two miles in length, leads from the Meppen station there; and Krupp's private benzine motor car was in waiting on that part of the track which runs past the boarding house.

The scenery viewed from this little road is less dreary than is most of the Meppen country. On the left flows the beautiful river Ems. In the rear, with its fine church, lies the little country town of which the name, as being connected with Windthorst, its late representative in the Reichstag, is familiar to all readers of German newspapers. The track presently turns to the right and plunges into a pine-forest; then high sandy dunes, which form the Meppen Switzerland, appear. A little later some detached houses and little gardens come into sight on either side. These lonesome homes in the ravines belong to those employés whose duties oblige them to remain near the proving-ground. A few moments more and the journey is over.

An immense and almost perfectly level heath, bordered on both sides by pine-forests, extends its length as far as the eye can follow. To this a bridge, 75 metres (246 feet) long, supported on trestled pillars, 6 metres (20 feet) high, forms a sort of gigantic portal. Below this bridge a long line of guns of all sorts and sizes stretch forth their threatening muzzles, as if to hold at bay a world of foes. On the right are some armoured emplacements; in the rear numbers of guns, gun carriages, and artillery waggons; while still further back are stored thousands of projectiles, many of which are painted either red or white.



PLATFORMS AND TRAVELLING CRANES AT MEPPEN PROVING-GROUND

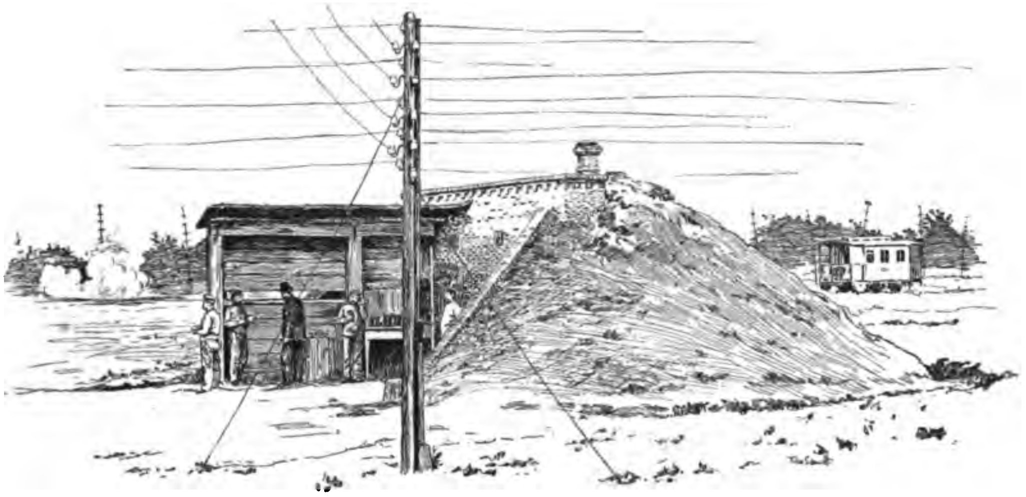
On the tracks which the bridge supports move two large travelling cranes with a capacity of 75 tons each. The middle yoke of the bridge is calculated to carry 200 tons, and these cranes can by their united efforts lift the 120-ton, 42-centimetre (17-inch) gun from its 16-axle transportation van and place it on its carriage. This "big gun" and its four brothers are the largest in the world. Their armour-piercing projectile, weighing 1000 kilogrammes, is stood upright as a monument on an elevation behind the guns' emplacement. It is the height of a tall man, and when shot from the gun by a charge of 410 kilogrammes (904 lbs.) of brown prismatic powder it has an initial velocity of 604 metres (1980 foot-seconds)—*i.e.*, an initial energy of 18,600 metre-tons (60,000 foot-tons).

Not much time was allowed for inspecting the monster, for the shooting experiments were about to begin. A 17-centimetre (6·7-inch) gun of 40 calibres length, mounted on a naval carriage was to lead. The man at the telephone in a small wooden booth behind the platform called out, "Track clear!" then "Attention!" All had stopped their ears. "Ready! Fire!" A yellow ball of fire appeared at the muzzle of the gun, a dull report resounded, and the projectile flew in a slightly curved line to a target which, at several miles distant, was visible above the horizon, passing while on its way through two frames strung with copper wire. From a position directly behind the gun, the eye can follow in its flight, a projectile of large calibre, for from one to two seconds. Then the small black disc disappears, and immediately afterwards there suddenly rises just beyond the target a cloud of sand and dust, the projectile having for the first time touched the ground. It then rebounds, and continues its course for five miles further.

On the day of the writer's visit, the appointed work was the testing of a certain kind of powder, such experimental determination of the qualities and usefulness of different varieties forming one of the most important tasks undertaken at the Meppen grounds. For the larger guns, in order to measure the gas pressure, both a crusher-gauge and a Rodman gauge are set in the obturation plate. The initial velocity is measured according to the Le Boulengé method described in the preceding chapter. In order to obtain double control, two apparatus worked by the same currents are usually employed.

In less than five minutes after a shot was fired, the data from the apparatus were returned, the effect on the target registered, and the principal ballistic results determined. It was decided to increase the charge for the next round by one kilogramme, the man at the telephone transmitting this order to the laboratory. We repaired thither, and found some men and elderly women busy preparing cartridges for the day's shooting. The powder consisted of short chocolate-coloured, hexagonal prisms, weighing 45 grammes (1·6 oz.) and having in the centre a perforation. These large grains are as hard as ebony, and are all exactly equal in form and size. The women build hexagonal piles of them, nearly approaching the diameter of the gun's chamber, and draw over each pile a bag of closely woven white cloth. One of these charges lay on the scales, and after its weight had, by adding a few grains, been corrected, it was bound up and sent on a narrow railway track to the gun.

On our way back we visited a little house completely concealed by earthen ramparts. Inside it, a more than tropical temperature prevailed: for along the walls ran heating pipes fed from the boiler house with steam. In this place the hygroscopic quality of the powders is tested, and during the cold season these are warmed to a medium temperature.

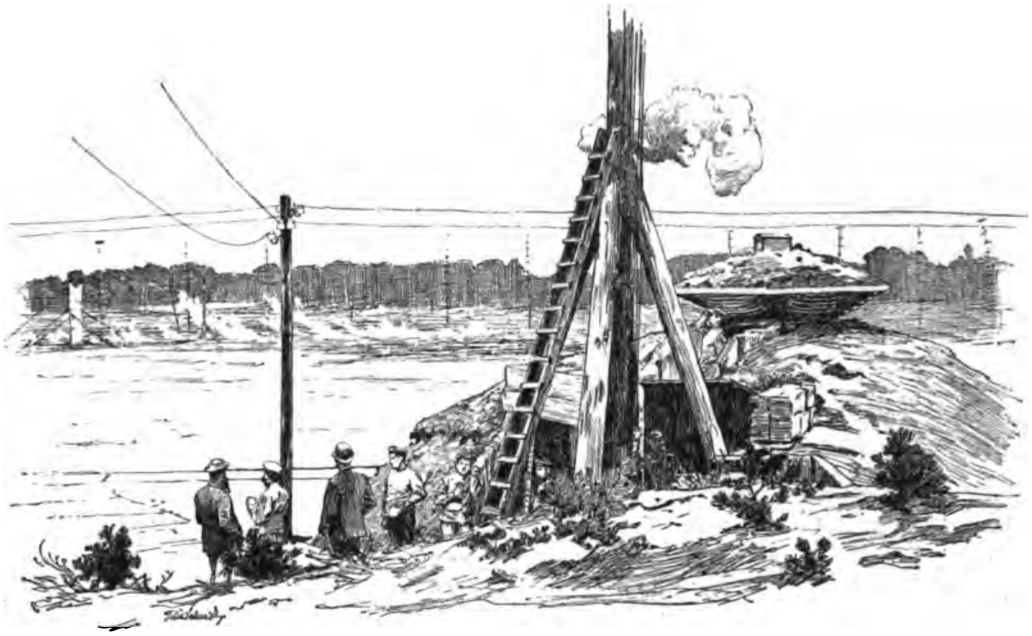


SAFETY STAND AT ONE THOUSAND FIVE HUNDRED METRES RANGE, AND MOTOR CAR WATCHING THE EXPLOSION OF A SHELL

On our return to the 17-centimetre gun, we see a 78-kilogramme (172 lbs.) armour-piercing shell, brought to its rear by a small crane attached to the gun-carriage and run home by a wooden rammer. Then the bag containing the charge is pushed in, and the breech is closed. The wedge has a perforation in the middle, into which a Krupp friction-fuse is screwed. Pulling a copper wire explodes the primer, sends its flame into the chamber, and ignites the charge.

We decided to observe the result of the next round from a position near the target. A railroad track runs along the side of the proving-ground, and the same motor car in which we came from Meppen took us comfortably and quickly to our destination.

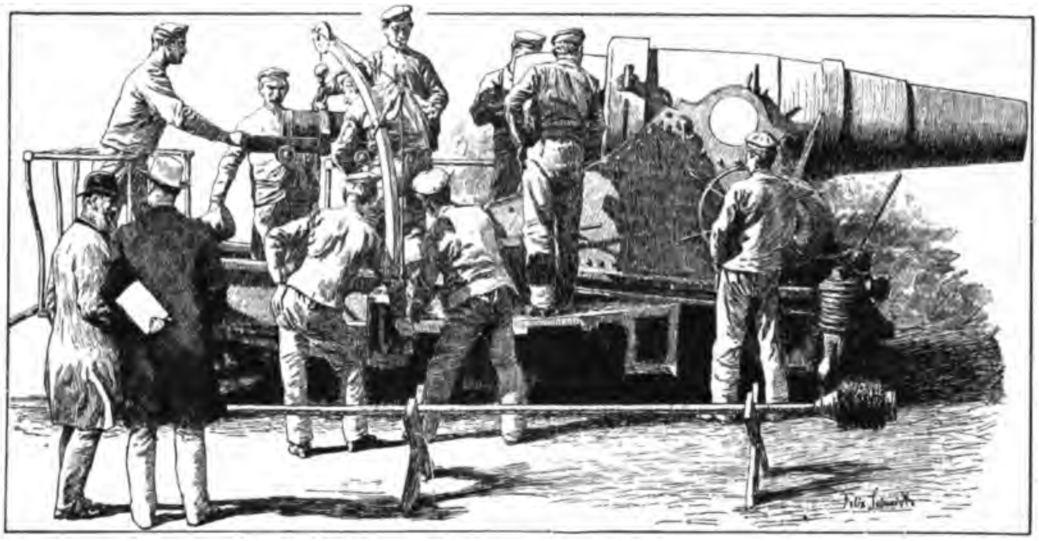
On the road thither the distance from the platform is at every ten metres marked by a pole, and to these poles are nailed cross-pieces which facilitate the reading of the range. The whole ground is surrounded by telegraph wires. Here and there are observation booths and safety stands, all of which are connected by telephone. When about a mile and a half distant from the platform, we stopped at one of the larger bomb-proof safety stands, placed near the edge of the pine-forest. Inside it we found a complete ballistic observatory and a small chemical laboratory, where various electric batteries (most of these being transportable) are filled. On the line of fire, at exactly 2500 metres from the muzzle of the gun, is placed the 5 metres (16·4 feet) square target, which is made of boards. In front of it, at a distance of fifty metres (164 feet) apart, are two high wooden structures supporting frames strung with copper wires. The second frame is about



SAFETY STAND AT TWO THOUSAND METRES RANGE. WATCHING THE EXPLOSION OF A SHRAPNEL two metres lower than the first, thus according with the downward curve of the projectile before it hits the target.

The telephone connection, and excellent training of the employés acquaint those near the target with all that transpires at the gun. The telephone operator not only transmits to the gun such orders as are given him, but also repeats aloud all that he hears there. The critical moment has come! we hear: "Track clear!"—"Ready! Fire!" and four and a third seconds afterwards the projectile crashes through the target, touches the ground about seventy metres further on, and ricocheting, fills the air with an uncanny puffing noise. The report of the gun does not, however, reach the ear until three seconds later. Some of the men hurry at once to the target, determine the point where it was hit, and where the ground was struck, and also readjust the broken wires on the frames. Meanwhile, the duration of the projectile's flight, its velocity at the muzzle, and near the target, and also the gas pressures according to crusher and Rodman gauges have been called out and recorded in lists and note-books by the men in charge of that department. The captain rapidly calculated the ballistic data, and then commanded: "Charge twenty-one kilogrammes, elevation thirty-four thousandths, one and a half thousandths to left." A few moments later the next shell broke through the target close to its centre. "Charge and elevation remain!" The regulation round of five discharges was then quickly fired. The ballistic results were satisfactory: 21 kilogrammes of the kind of powder used gave to the 78 kilogrammes projectile an initial velocity of 674 metres (46·3 lbs., 172 lbs., 2211 foot-seconds). The last three rounds struck the target less than one calibre from the centre line, one of them hitting it almost exactly in the centre, another at 80 centimetres above, and the third at 50 centimetres below it (31·5 in., 19·7 in.). To determine the duration of flight, the man in charge, on hearing the call "Attention!" puts a telephone to his ear, and when he hears in it the report of the gun, presses the button of a chronometer which indicates the hundredth parts of a second; and a second pressure stops the hand of the time-piece at the moment when the projectile strikes the target or the ground. As the result of several years' practice, the accuracy of these measurements is within 0·02 of a second. This fact has been proved by controlling calculations.

The writer could not refrain from expressing his admiration of the rapidity and precision with which all this work was done. Here, again, as well as in the crucible foundry, he noticed the exactitude of each separate individual, and the perfect regularity of their united performance, while at the same time there was in this nothing machine-like, nor anything which conveyed the impression of military drilling. And the manner in which the director of the proving-ground, while in the midst of writing down the observations, making calculations, and giving his orders accordingly, can at the same time answer the eager questions of a visitor, and explain ballistical phenomena, is indeed remarkable. He is also a *virtuoso* in using the sliding rule. That scale of polished ivory divided into logarithms belongs as an attribute to the captain of Meppen, as do thunderbolts to Jupiter. He gave as a souvenir to the writer an old one with which he said he had learned the art of using it. And after practising with it, the writer now much regrets that he was not taught to use it twenty years ago.


LOADING A TWENTY-EIGHT-CENTIMETRE (11-INCH) HOWITZER

The series of shooting tests of the kind just described was interrupted by some rounds of high angle fire from howitzers and mortars, which were especially interesting. The writer had already, in the gun machine shops, made the acquaintance of these comparatively short and light guns, intended by their high curved trajectories to attack from above covered fortifications and armour-clad vessels. The first piece of this kind tried was a 28-centimetre (11-inch) howitzer, and the first round was fired with a charge of 2·85 kilogrammes (6·28 lbs.) of cubical smokeless powder, and at an elevation of 60 degrees. We repaired to a point of observation, 2000 metres distant from the gun. The captain calculated the spot where the projectile would fall, and by telephone ordered the aiming gunner, "90 thousandths to left." "But then the gun will aim directly at us!" "Quite true, only the projectile does not, as you seem to think, describe a simple vertical arch, but owing to its rotation deviates considerably to the right. With rifled guns this is always the case, but the deviation is much slighter with guns of flat trajectories. Perhaps you may have noticed that with the 17-centimetre gun we fired 1½ thousandths to left. But look now!" A flash from the howitzer, and five seconds later the thunder of its report rolls by, over the heather and the woods. There is an instant of perfect silence. Then from high up in the clouds there comes a rustling noise, at first low, then rapidly growing louder, and sounding as if a flock of gigantic birds were flying over our heads. Instinctively we gaze upwards, and from among the clouds see tearing down head foremost the big shell of 345 kilogrammes (760 lbs.) weight. Three seconds later it has, on the spot calculated beforehand, dug itself three metres into the ground. The impression conveyed was, that a man-of-war at anchor would certainly be disabled by the enormous bursting charge of a similar projectile.

SEVEN-AND-A-HALF-CENTIMETRE (3-INCH) MORTAR CARRIED BY THE GUNNERS

It may here be mentioned, that howitzer batteries are placed on the coast in positions where hills, or depressions of the ground, conceal them from view. From a post of observation, situated at a considerable distance from the battery, an officer, who by means of a range-finder, determines the position and movements of the enemy, telephones orders for sighting the guns, and then at the proper moment himself fires them by means of an electrical contact. In the experiment just described, the projectile remained in the air for 31·2 seconds. With a longer range, say of five miles, it remains there for more than a minute. In the meantime, the position of a ship, which is moving even only at half speed, will be altered by several hundred metres ; a circumstance which must, when the gun is laid, be taken into account.

For the visitors' benefit, a second round was fired from the same howitzer ; but with a very small powder charge. This time the projectile rose only to about the height of the spires of Cologne Cathedral, and in ten seconds hit the ground at a distance of 288 metres from the gun. It was possible to follow its entire flight with the eye. On this occasion, the projectile did not come down head foremost, but remained parallel to the position in which it emerged from the gun, so that on the summit of its trajectory it was crosswise, and it finally struck the ground with its base.

This observation quite naturally turned our attention to the laws of the rotation of projectiles. A long projectile receives from the twisted rifling of modern guns a rapid rotation around its longitudinal axis, which tends to keep it during its flight parallel to itself. In case that, on the contrary, the axis of the projectile remains in the trajectory, and consequently gradually changes its direction, this is caused by a very considerable lateral pressure acting on it. Such pressure comes from the resistance of the air resulting as soon as the axis diverts a little from the trajectory. The lateral pressure of the air does not steer a projectile as it does an arrow, but the rapid revolutions cause the air to give way. The projectile thus moves on in a conical oscillation which by degrees brings down its point. It may be said that the projectile fairly screws itself into the trajectory—this rather complicated action being, as has been said, the result of a strong resistance of the air. When this is absent, or when it is insufficient, as with the abnormally small initial velocity of the last experimental round described, the axis remains parallel to its first direction.

Experiments similar to those made with the big howitzer were tried with a 7·5-centimetre (2·95-inch) mortar, a liliputian gun, scarcely as long as a man's forearm; and, in contrast to the large guns, looking like a toy. And yet this rifled mortar, with 200 grammes (7 oz.) of powder threw a 4·5-kilogramme (9·9-lb.) shell, belonging to a field-gun of the same bore a distance of 3000 metres. As this gun with its carriage and wooden platform weighs but 100 kilogrammes (220 lbs.), four men can easily carry it, even over a very difficult country. In a colonial war, for instance, it can be used to bombard retrenched positions.

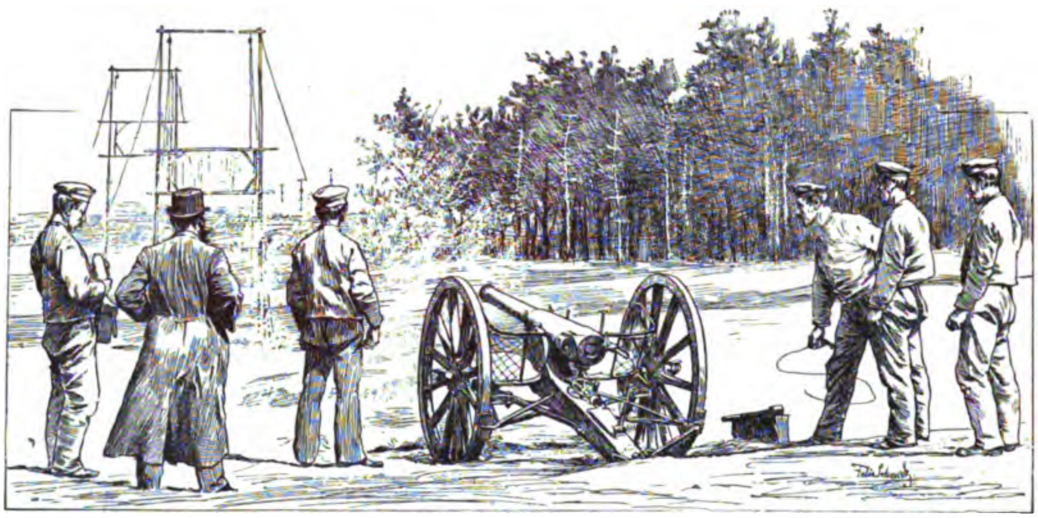
While watching the mortar's discharges, we approached the armour-clad targets. Even since the Meppen proving-ground has existed, the contest, waged there between cannon and armour has been increasing. We saw wrought-iron armour-plate, of half a metre in thickness, perforated by shot, and shattered compound armour-plate; both trophies of a time only a few years back, when the cannon was incontestably victor in the struggle. When the Essen factory began, by means of the gigantic plant described in a former chapter, to manufacture armour itself, the testing of armour-plates naturally became one of the chief tasks of the proving-ground. These experiments demanded very considerable preparations—such, for instance, as walls of oak, one metre thick, propped by iron stays and rafters, to which the plates are fastened, as on a man-of-war, by iron bolts of several inches in diameter. We found some of the recently tested plates unscrewed, and so had an opportunity to examine them thoroughly. They are made of a hard and tough alloy of nickel and steel. A plate of the comparatively modest thickness of a quarter of a metre will, at fighting distance, resist all projectiles of modern naval guns up to 21-centimetre (8-inch) calibre. The front of one of these plates showed five holes with ragged edges, while on the back were five bulgings, scarcely larger in diameter than the projectiles, and with small cracks in their centres only. It is a characteristic of this plate material, that steel armour-piercing shell will not stick in it, but either whole or else broken in the middle are thrown back about ten metres. But some of the plates which had been tested were of still harder material, and the impinging steel shell, while merely producing cracks or almost imperceptible dishings, had themselves been shattered to pieces. A near future may show the world still more astonishing results.

By stating the fact that every armour test costs about 20,000 marks

(£952), some idea may be conveyed of the sacrifices which are entailed by the effort to manufacture ship's armour capable of successfully resisting modern ordnance.

FIRING A TWENTY-ONE-CENTIMETRE HOWITZER

Shooting at 2500 metres range, and in the manner above described, obtaining the accompanying observations and measurements, occupied all the remainder of this and the whole of the following day. One after another guns of all sizes were fired; field-guns, rapid-fire guns, and among the rest two of the powerful 28-centimetre (11-inch) guns. One of these, 33 calibres in length, was mounted on a centre-pivoting carriage, the other, 40 calibres long, under a revolving cupola with complete hydraulic movement, for which the water came under pressure from the engine-house 300 metres distant. The different operations of loading, elevating, traversing and cleaning, are so interesting, that in watching them, together with the observation of the loud reports, the starting of the projectiles, the recoil of the guns, and the working of their carriages, a visitor to whom all this is new, and who sees it under the intelligent guidance of an expert, is rendered insensible not only to the flight of time but also to cold, rain, and fatigue.



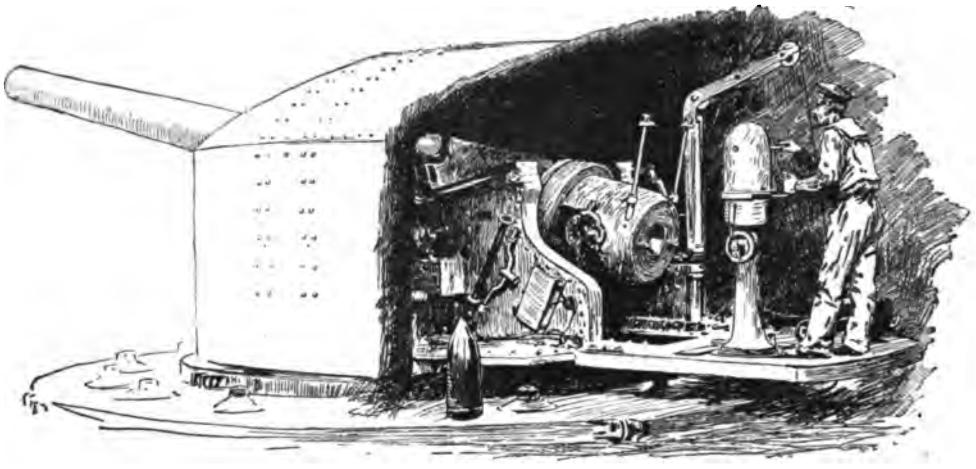
MEASURING VELOCITIES. FIRING THROUGH THE FRAMES WITH SMOKELESS POWDER

In the evenings when safely ensconced in the cosy little hotel, the writer thought again over all he had seen and heard. He studied Krupp's tabulated data, and pored over some learned books which opened to him new horizons in the domain of ballistics. Into some of the principal teachings of that difficult science he will now try to initiate his readers.

When a projectile leaves the muzzle of a gun, it is governed by the laws of gravitation. At the end of the first second it will have fallen about five metres, and at the end of the following second four times as far. This sinking of the projectile during its course causes the downward curve of the trajectory. A 17-centimetre projectile will reach the target from a distance of 2500 metres, in 4·18 seconds. Now in that length of time it will, in accordance with known rules, have sunk 85·7 metres (274 ft.). Consequently, in firing such a projectile, the gun must be aimed at a point which is vertically the same height above the target.

In the aiming apparatus of a gun, there is placed near the trunnion a pointed steel cone, known as the front sight, and near the breech a prismatic sliding rod, called the rear sight; which latter can, by an ingenious arrangement, be screwed up and down under a right angle to the axis of the bore. The height of the rear sight can be read on its graduated scale, the distance by which it is separated from the front sight being divided into thousandths. On top of the rear sight, the 17-centimetre gun has, instead of a notch, a small frame strung with one horizontal and two vertical threads. When the gun is aimed, the point of the front sight should appear between the vertical threads, and on a level with the horizontal one. The frame can be screwed several centimetres to either side, and this deflection can be read on another graduated scale. When both scales mark zero, the line between the sights runs parallel to the axis of the bore. If the rear sight is screwed up to line 34, the elevation is thirty-four-thousandths. The 17-centimetre gun had, it may be remembered, this elevation, which at a distance of 2500 metres, means a height at the target of 85 metres. This is the same figure deduced from the projectile's time of flight.

This method of determining the correct angle of elevation is of course only of theoretical value to the artillery officer, since he cannot be near the target with his chronometer in his hand. He must judge of the elevation necessary for a certain range by the only datum at his command—that of the initial energy of the projectile. It is therefore necessary for him to have an exact knowledge of the trajectory. The theory of the flight of projectiles is, however, one of the most difficult problems of physics, and has not as yet been solved by purely mathematical treatment. A professor's formulas of ballistics are based on the observations of the proving-ground, which have been translated into mathematical hieroglyphics. The retarding influence of the atmosphere forms the difficulty of the problem; that is to say, the complication of the laws which govern the resistance of the air as exerted against a solid body moving through it at a varying rate of speed. That resistance which in moving the hand is scarcely perceptible, becomes decidedly disagreeable if the head be put out of the window of an express train moving at full speed. Now, if the train moved with the velocity of an artillery shell, the head would be torn off by the air just as if it had been hit against the pillar of a bridge. The experiments with the 17-centimetre gun showed that the projectile had near the target an average velocity of 506 metres, whereas its velocity at the muzzle was 674 metres; therefore an energy of 1806 metre-tons had been reduced to 1018 metre-tons (2200 foot-seconds to 1660, and 5800 foot-tons to 3300). If this loss of 788 metre-tons is divided by



TWENTY-ONE-CENTIMETRE NAVAL GUN WITH ELECTRIC GEAR

the distance traversed it shows a mean resistance of 316 kilogrammes (700lbs.). This figure is only an average, for at the muzzle the resistance is greatest, and in a certain proportion it diminishes with the velocity. The resistance of the air was formerly supposed to change proportionately to the square of velocity. The numerous series of observations on the Meppen ground have, however, demonstrated that this is only approximately correct for velocities below 240 metres and above 400 metres (below 787 foot-seconds, above 1312 foot-seconds). For between these limits the resistance augments much more rapidly, being in the middle of the interval even proportional to the fifth power of velocity. It has not yet, however, been found possible to express the function of resistance in a set mathematical formula. The difficulty was met by experimentally measuring the decrease of speed in the flight of a projectile of normal design for all velocities from 1000 metres (3281 foot-seconds) downwards. Thus were compiled Krupp's tables, of which mention has several times been made, and which have been used in all recent ballistic calculations. According to these tables, with the projectile of the 17-centimetre gun the resistance near the muzzle was 400 kilogrammes (882 lbs.), and at a range of 2500 meters (8200 feet) only 238 kilogrammes (525 lbs.).

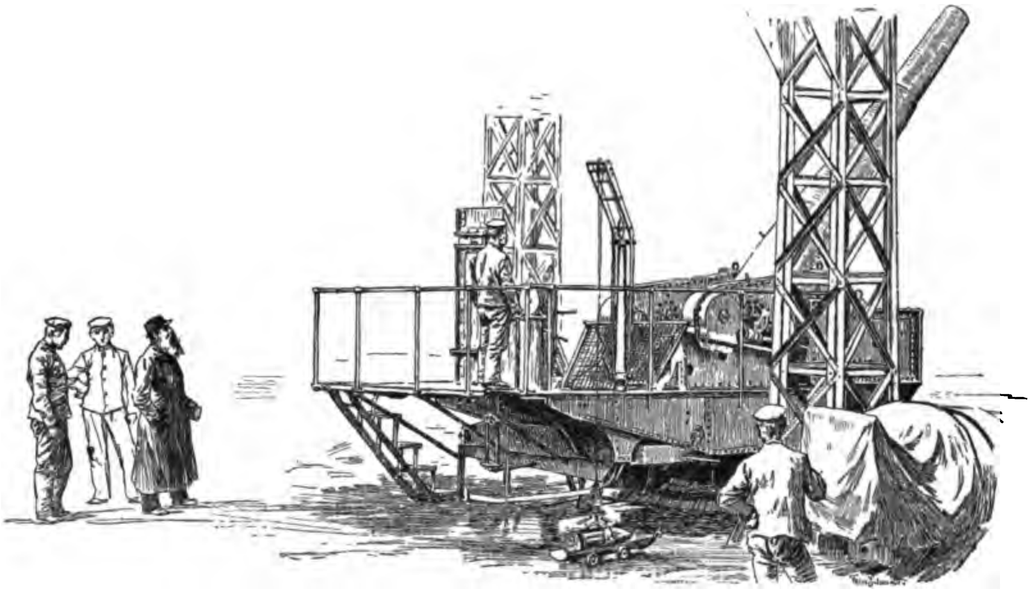
The resistance of the air deprives the trajectory of a symmetrical parabolic form, making its line of descent much steeper than that of ascent. The actual velocity of the projectile in its curved line of flight must not be confounded with the horizontal velocity with which it advances in a straight line towards the aim. The numbers in the tables refer only to the latter, just as if the projectile were not subject to the laws of gravitation. But an empirically established law permits the use of the same table for all trajectories resulting from projectiles of equal size and initial energy, although at different angles of elevation. Or, to express this more plainly: this law says that when the sun is in the zenith the shadow of the projectile will always travel over the ground according to the data of the tables, no matter what the height of the summit of the trajectory may be.

So far the air has been treated of as a resisting medium of fixed quality. But in reality its density changes considerably, according to the temperature and barometric variations. Fortunately, however, the resistance is in direct proportion to the density of the air, and the result of the calculation only has to be multiplied by a constant factor, which must, it is true, be for every experiment determined by observations of the thermometer, barometer, and hygrometer. The direction and force of the wind must also be taken into account. The proving-ground is therefore provided with a complete meteorological observatory. A Robinson anemometer is placed on a lofty iron scaffolding, from the platform of which may be obtained a fine view of the proving-ground and surrounding country. Then the shape of the projectile plays, of course, an important part. The tables are made for a normal pointed projectile. For any other shape another constant factor must be brought into the calculation. That factor is deduced from the difference between the observed retardation and that given in the tables. For instance: the resistance offered to a projectile with a mushroom shaped head is 1·4 times that given in the tables for a normal projectile.

Lastly, it remains to be seen how the weight of a projectile influences the trajectory and the energy. Suppose that two projectiles are of the same dimensions, but that one of them being hollow weighs only half as much as the other. Then if they start with equal velocity, the heavier one (although the resistance of the air is for both of them the same) will have lost after a flight of two metres the same amount of speed as the lighter one will have lost at the end of one metre. Given equal velocities, the retardation is in inverse ratio to the weight on the cross section. Krupp's tables are designed for a weight of 1 kilogramme on the cross section, *i.e.*, for projectiles of normal design, weighing as many kilogrammes as the cross section measures in centimetres square (14·22 lbs. to the square inch). The armour-piercing shell of the 17-centimetre gun had 674 metres initial velocity. Beside this number the table reads 41, that figure giving in metres the distance at the end of which the velocity of a projectile weighing one kilogramme will have lost one metre. But the projectile in question weighs 78 kilogrammes, and has a cross section of 233 centimetres square, that is, only 0·333, or exactly $\frac{1}{3}$-kilogramme for every centimetre. As 13·6 is a third of 41, we know that when this projectile attains a distance of 13·6 metres from the muzzle, it will have lost one metre of its velocity.

Therefore, according to what precedes, the heavier projectile will (all other conditions being equal) retain, in passing through the air, more of its energy than will the lighter projectile. It is worth while to look more closely into this important matter. It must, in the first place, be borne in mind that a given powder-charge for which the gun is designed, represents a given amount of energy; and that from a powder of good quality, a lighter and a heavier projectile will both receive about the same energy. This energy is proportional to the number of kilogrammes multiplied by the square of the velocity. As many times as the weight is greater, so many times smaller will be the square of velocity, and *vice versâ*. So, if to the 78-kilogramme shell with 674 metres velocity is compared another shell of 500 metres velocity, the weight of the latter must therefore be 142 kilogrammes. The first shell, on a range of 3060 metres, loses half its energy, the second one loses on the same range not quite one-third of it; and can, consequently, at all fighting distances, pierce a considerably thicker armour. With regard to accuracy, the lighter projectile has, however, the advantage. It traverses the distance of 3060 metres in 5·42 seconds; which fact permits of its being fired at an elevation of forty-eight-and-a-half-thousandths. A shell of 142 kilogrammes would under the same conditions, take 6·58 seconds to reach the target; necessitating, therefore, its being fired under an angle of seventy-and-a-half-thousandths. As its falling angle would be determined in the same proportion, the probability of hitting the target would be smaller.

There is, consequently, much to be said in favour of the lighter projectile and more extended trajectory, when the piercing capacity is of minor importance; as when, for instance, the projectile is directed against living aims or thin armour. But even in such cases the effect of the greater mass of the other projectile, of the number of balls a shrapnel contains, and of the destructive force of a larger bursting charge, must be taken into consideration. With regard to the monster guns forming the main batteries of battleships and coast defences, the question is somewhat different; for their efficiency depends upon the energy in hitting, and the fact that the heavier projectile best retains that energy thus becomes of the first importance. But the *pros* and *cons* of these difficult and complicated questions it remains with experts to weigh.



TWENTY-FOUR-CENTIMETRE COAST DEFENCE GUN AT FORTY-FIVE DEGREES ELEVATION FOR TWENTY KILOMETRES RANGE

These pages devoted to ballistical problems will enable the reader to understand why neither at Essen nor at Meppen they will begrudge the millions of money, nor the great exertions involved in keeping up the proving-ground, and in carrying out its various experiments. Only in this way could the manufacture of guns and ammunition, and also the art of shooting, have been raised to a degree of perfection which excites not only the admiration of experts, but also that of a great public which is rendered somewhat callous by the numerous marvellous results of modern technics.

In concluding this chapter some special ballistic data may be given, which although not mentioned in the range tables of cannon may yet be of interest to the reader. When at some great international exhibition one of the "big guns" is admired by the public, among the first questions asked is, "How far can you shoot with that?" The people who make this inquiry scarcely understand its meaning. The range of every gun depends on the angle of elevation. A 30·5-centimetre (12-in.) Krupp gun, of 40 calibres length, at 8 degrees of elevation, carries five miles; the shell, weighing 455 kilogrammes (1000 lbs.) fired with an elevation of 25 degrees, would travel 10 miles; while the extreme limit of range would only ensue with an elevation of 45 degrees.

In order to determine by experiment a maximum range, Krupp had made for a 24-centimetre (9·45-in.) coast defence gun, of 40 calibres length, a special carriage permitting the highest elevations. On the Meppen proving-ground, in the spring of 1892, in the presence of H.M. the German Emperor, this gun with a charge of 42 kilogrammes (92·5 lbs.) of smokeless powder, fired a 215-kilogramme (474 lbs.) shell, a distance of 20,226 metres (22,120 yards or 12·6 miles). The curve of the trajectory would have passed over the Alps near Mont Blanc, and its summit, which reached an altitude of 6540 metres, would have risen, by the added height of Faulhorn, above the top of Mont Blanc. Although this is the longest range ever reached in an actual experiment, it is not the limit which could to-day be attained. The 30·5-centimetre (12-in.) gun, would, with 45 degrees of elevation, project its shell 25 kilometres (15·6 miles), and thus Potsdam might be bombarded from the Brandenburg gate of Berlin. While a judicious ordnance officer might consider the probable success of a cannon shot beyond a range of four miles, as not being proportionate to the expense entailed in ammunition and ordnance, these astounding data, none the less, bear testimony to the greatest triumphs of metallurgy and mechanics, in alliance with all the means of exact science.

CHAPTER XIX

THE BENEVOLENT INSTITUTIONS OF KRUPP'S CAST-STEEL FACTORY

A DESCRIPTION of Krupp's Institution for the benefit of his employés did not enter into the original plan of this work. Certain circumstances, however, gave the writer leisure to investigate personally, as well as to study the working of these remarkable establishments, which according to the verdict of those best qualified to judge, are in their way as worthy of renown as the great factory itself. It was necessary to give up a week to visiting the vast domain, and to examine a large number of pamphlets and statistical tables before the writer felt himself competent to deal with so intricate a matter. But, that once accomplished, it is a pleasure to devote an extra chapter to the subject. It is dedicated to the philanthropist, to whom it will appear like a ray of sunshine, making flowers spring forth, even on this arid soil, where fire and gunpowder reign.

The system of relief funds shall be first mentioned. This may appear to be a dry and unattractive subject, but it is a field where the sower's efforts are rewarded by rich harvests.

In the middle of the fifties there already existed in the Essen factory a fund sustained by the contributions of its members, and by those of the Krupp firm. It not only afforded its members assistance in cases of illness or death, but also granted pensions, or gave special help in cases of disability from old age or accident. This excellent system was abandoned in 1884 on account of a law then enacted in the German Empire, which forbade the combination of a system of pensions with sick benefit funds.

Therefore, in conformity to the new law, two separate funds were established for the cast-steel factory of the Fried. Krupp firm—a pension fund and a sick benefit fund. Although the contributions of the members belonging to the sick benefit fund only amounted to 1·7 per cent. of their average wages, the help extended exceeded that prescribed by law. However, it was unfortunately impossible to continue this system after the law promulgated on April 10th, 1892, which enforced equal benefits for all members, and also forbade certain extra payments, in particular an additional one which was proportioned to the number of children. The sick benefit fund was consequently re-organised; the contributions of its members were reduced by 0·4 per cent., and the help given was limited to that prescribed by law. But it was found possible with the aid of this 0·4 per cent. to create another optional sick insurance fund, securing to its members all the advantages of the former system—the firm granted to this private fund a contribution of 36,000 marks (about £1800) a year; and all its members, thanks to this munificence, are thus entitled to assistance from three independent funds—the sick benefit fund, the sick insurance fund, and the pension fund. In addition to these funds, there have been special organisations established which secure to their members, and to the pensioners of the factory, free medical services and medicines at low rates.

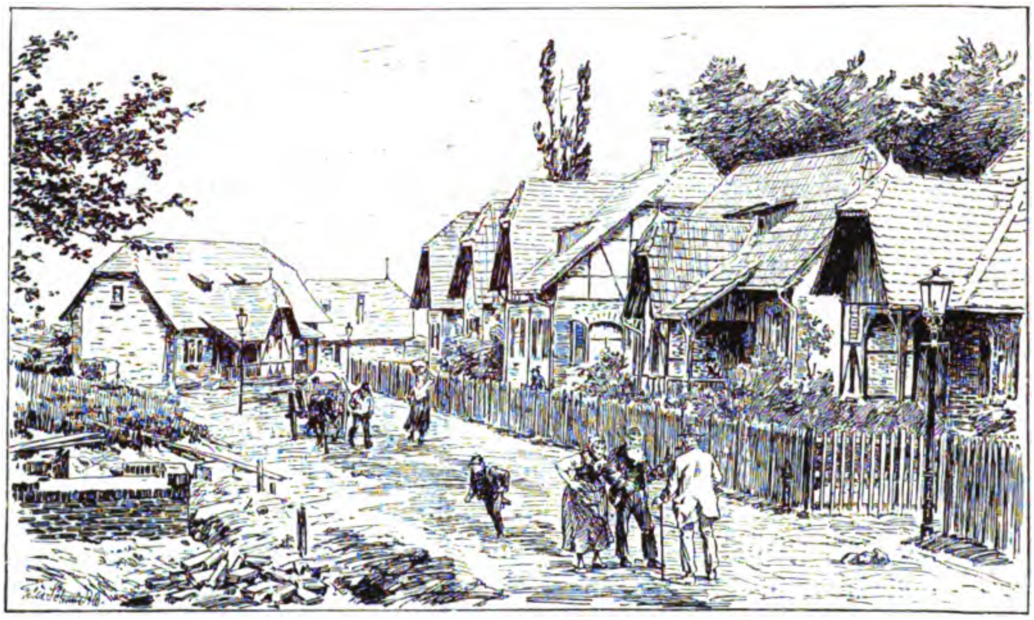
The pension fund above mentioned, known as the Workmen's Widows and Orphans Pension Fund, is a development of the pension organisation established in 1884, from which it obtained the greater part of a capital exceeding a million and a half marks (£71,400). Independently of the insurance granted by law, this fund entitles every workman in Krupp's employ, against a premium of 2·5 per cent. of his average wages, to an old age pension amounting to 40 per cent of his last average wages after

20 years' service, and in case of especially hard work after 15 years. For every additional year of activity, an additional 1½ per cent. is granted up to a maximum of 75 per cent. The highest amount of annual wages on which this pension can be calculated is 2000 marks (£95).

This same fund also pensions the widows and orphans of the workmen. When a member dies, his widow receives one half, and each child 5 per cent. of his pension; or, if the mother is also dead, each child receives 7·5 per cent., up to a maximum total of 90 per cent. Partially incapacitated workmen are granted portions of pensions.

As the disbursements of the fund increase yearly, while its receipts do not, it is evident that it could not pay such pensions were it supported only by the contributions of its members. In order to secure their employés against any reduction of pensions, as well as against any augmentation of the percentage paid by them, the firm in 1891 decided to give yearly to this fund a sum equalling the united contributions of its members—*i.e.*, about half a million marks per annum. And this is not all. Herr F. A. Krupp, in remembrance of the glorious victories won by Germany a quarter of a century ago, recently endowed this fund with one million marks. In addition to this munificence, the firm has behaved most generously with regard to the insurance against old age and incapacity, established by a law of the German Empire promulgated on June 22nd, 1889. According to this law every man belonging to the working class who is obliged to insure, pays one per cent. of his wages into the Imperial insurance fund, an equal amount being paid in by his employer; this employer's portion amounting at the Krupp factory to the considerable sum of 110,000 marks (£5200) a year. Every workman thus insured, when he becomes permanently disabled, or when he reaches his seventieth birthday, receives from the Government, after fulfilling certain formalities, a small pension, which at his death ceases, his widow and children getting nothing. Now in these cases Krupp's fund is entitled to deduct the entire amount of the government pension from the much larger amount paid by itself. However, in point of fact only one-half is thus deducted. To make this clearer the following example is given. Krupp's fund pays a workman whose annual wages are 1200 marks, and who has served thirty years, 660 marks per annum, whilst the government pension is at present about 150 marks, an amount which by longer duration of insurance will be increased to 310 marks. A Krupp pensioner will thus receive a total amount of between 735 and 815 marks a year; his widow draws 330 marks and every child 33 marks, or else 49·5 marks respectively.

The constitution of this benevolent fund, which at present possesses a capital of nearly five million marks, and pays out more than half a million a year in pensions, does not permit of its being drawn upon in cases of disability from accident. For this contingency is, in the German Empire, provided against by a law of insurance against accident. Into this Government fund the Krupp firm is now obliged to pay an annual premium of about 185,000 marks (£8800).



COLONY "ALTENHOF"

In addition to these great funds, a few others of more restricted scope exist in Krupp's cast-steel factory, all of which were originated by the philanthropic and generous tendencies of the present owner of the works, to whom they also owe their financial solidity. Immediately after taking possession of the factory he created, in memory of his father, the "Krupp

Workmen's Aid Fund," endowing it with one million marks. It is intended to serve as a supplement to the pension fund, which, as has been stated, only pays pensions after twenty years', or in exceptional cases after fifteen years' service. The interest of the new fund is used to assist those workmen who are disabled before becoming entitled to a pension, and in case of death, to help their widows and children. As this is quite outside the official aid given to old age, and the public care of the poor, the workmen and their families are well protected from any real distress.

Then in 1890, Mr. F. A. Krupp, for the benefit of those of his employés whose income exceeds 2000 marks, and their widows and orphans, established yet another fund, which he had endowed with its original capital of half a million marks. In addition to an entrance fee, each member pays in 3 per cent. of his annual income, whilst the firm yearly contributes an amount equalling the added payments of the members. Every new employé is obliged to join this fund, which has already increased its capital to two million marks, and which after only five years' service, pays in cases of disability pensions equalling fifteen-sixtieths of the salaries, and for each additional year one-sixtieth more, up to a limit of forty-five-sixtieths. Widows and orphans receive pensions in the same proportion as from the Workmen's Pension Fund. In the cases of high salaries, premiums are not collected, nor pensions paid, for more than a limit of 10,000 marks (£478), of the annual income. In a fund entirely supported by the firm, the salaried employés are very favourably insured against accidents.

In 1877, during Alfred Krupp's lifetime, a Life Insurance Association of employés was founded, which he endowed with a sum of 50,000 marks (£2380), in order to form a nucleus for the fund. The membership of this association, of which the benefits are increasing and spreading more widely every year, is open to all employés and workmen. Its board of directors, backed by the credit of the great firm, acts as intermediary between eight large life insurance companies and the persons insured. This board attends to all formalities and troublesome details, controls the collection of the premiums, and receives the insurance money; in a word, transacts for those insured all necessary business. One half of the bonuses paid to the association by the insurance companies is received by the policy-holders in the form of deductions from the amount of their premiums. The other half is put into the fund of the association, which in return undertakes to protect policy-holders against cancellation in cases of temporary insolvency, and to extend other special aid to members who, through no fault of their own, have become destitute. All members of the association benefit by special rates of insurance, the reduction in their favour at present amounting to 8 per cent. In cases of sickness, all premiums are paid by the association during the time a member receives assistance from the sick benefit fund and for one month after the cessation of such assistance. The Krupp firm not only subscribes to this association, but also has its business transacted by its own employés and without making any charge. The importance of the association is illustrated by the fact that in 1894 the sum insured amounted to four and a half million marks (£214,200), divided between 2466 policies.

The Krupp firm also interests itself in the economies of its workmen. It has not been found necessary to organise a special savings bank, as such banks exist both in Essen and other neighbouring towns. But the stamp currency of the savings banks can be obtained at the counters of all the firm's supply-stores, while the saving spirit is encouraged in its schools, and especial pains are taken to rouse this spirit among the apprentices. Every apprentice is paid from the beginning of his service; his daily wages rising from 60 pfennigs (7½d.) to 2·50 marks (2s. 6d.). A part of his wages is kept back, and only paid at the termination of his apprenticeship. Thus, 111 apprentices, who in 1892 completed their four years' time, all received a little capital averaging 635 marks.

It should also be mentioned that Krupp allows all his workmen to deposit money in sums of from 200 marks (£10) upward, in the different firm funds, at 5 per cent. interest. In the fact that this privilege is one largely availed of may be found a proof that, in spite of all that has been said against capitalistic industries, an economical workman not only makes a good living but is also able to lay aside.

This list of all the funds organised for the benefit of Krupp's employés, may be fitly completed by a mention of Krupp's Endowment Fund (*Krupp-stiftung*) for the town of Essen. When Herr F. A. Krupp took possession of the works, he generously presented the town of Essen with the sum of half a million marks; subject to the condition, that the interest of this sum should be devoted to objects calculated directly or indirectly to better the moral and material condition of the lower classes. The administrators of this fund are at present directing their efforts to the erection of workmen's dwelling-houses and cheap public baths.

* * * *

Should the half-million marks which the Krupp firm is obliged annually to contribute to the Imperial funds for the benefit of working men be credited to its benevolent account? It may be objected that such charges, imposed by law on industrial establishments, increase the price of their products and are, in fact, finally paid by the consumers. And in this there is some truth, but the voluntary gifts of a single manufacturer tell a very different tale. The three millions donated by Krupp, and the sum of over half a million marks yearly contributed by the firm to private assistance funds for the benefit of their employés, are undoubtedly the outcome of philanthropy and generosity. It is not worth while to question whether such munificence fulfils its end and whether it is received with gratitude. It must be admitted that many prominent men who have devoted much attention to such subjects, and who feel a lively sympathy for the working classes, have arrived at the conclusion that it is wiser not to allow workmen benefits which can be looked upon as charities, or even as presents. Perhaps circumstances may sometimes justify such an opinion, which however cannot, as a general rule, be admitted to hold good. There still exist in Europe many great industrial establishments where the employers and the workmen do not look upon each other with enmity and suspicion, but where, on the contrary, they unite in working for the needs of civilisation, inspired by a strong feeling of mutual confidence. Let him who questions this, go after working hours to Kronenberg, or to any one other of Krupp's workmen's towns; let him then make the acquaintance of any mature workman or foreman, and turn the conversation upon the directors, or the young master, or his predecessor, now in his grave. He will soon understand that it is quite possible for a master and his head officials, when actuated by good feeling, to create and to maintain, by their dignity and tact, excellent relations between themselves and their workmen. But if the kind feeling does not exist among those who command, pecuniary sacrifices will be of no avail.

A well-organised system of aid-funds is certainly of great value, both with regard to the welfare of working men and the maintenance of public order. At the same time, many workmen, especially among the younger self-confident men, to whom the reverses of life have not yet taught wisdom, do not, it must be admitted, relish such protection. Every pay-day reminds them of the money of which they are deprived, while the benefits which they

A STREET IN "KRONENBERG"

will derive when illness or old age comes upon them, present themselves to their minds only as far distant and uncertain eventualities. The whole organisation is by such men considered an unwelcome guardianship, interfering with the free disposal of what, after all, belongs to them. And, in point of fact, all rules which force a man into a regular mode of life and compel him to invest a portion of his earnings as an insurance for his future, do to a certain degree restrict the independence of the individual. But surely, for the average man, what he thus obtains is of much greater value than the maintenance of an independence which is partly fictitious and partly worthless. It is however idle to expect, from the persons whom they benefit most, much gratitude for these useful organisations. And now enough has been said about assistance funds.

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Happily there exist, in connection with the factory, other benevolent institutions, whose benefits being more immediate are therefore less disputed. These are free from the odium attached to guardianship and assistance, and, superficially regarded, appear to be merely business arrangements between master and men, which are advantageous to both parties. Of the first importance are those measures taken by the factory to provide board and lodging for the workmen.

Early in the sixties, Alfred Krupp began to build what is now called West-End Colony, which immediately adjoins the factory. From the beginning, he decided in favour of large, substantially-built houses, several storeys in height, fulfilling all sanitary requirements, but, in order to make the rents as low as possible, in all other respects very simple and devoid of useless ornamentation. For they were expressly intended for workmen obliged to be extremely economical, and not for those to whom a few marks more or less spent in yearly house-rent are of small importance. He knew that the very poorest class of workmen, in rapidly growing cities, meet with the greatest difficulties in finding decent lodgings, and that they are the ones who, comparatively speaking, pay the highest rents.

In the years of economical progress following the creation of the new German Empire, the building of workmen's houses was undertaken on a vast scale. These dwellings are still looked upon as models of their kind, and experts come from all countries to see them—another proof of the broad and practical intelligence of the founder of this great workmen's colony. In the first place he understood that, under the prevailing local conditions, it was wiser to erect all the buildings close together, by which system the general provisions for health, comfort and security could be made in the simplest and cheapest manner. Also, all the tenants were thus brought near their churches, schools, markets, shops, baths, and places of recreation. Wishing to remain the proprietor and master of the colony, he only let, and never sold, any of the houses. The rents demanded were not abnormally cheap; Krupp's idea being that, although the rate of interest should be very low, the immense capital invested should still make some return. He wished to give tenants the advantages of sufficiently roomy and, above all, sanitary dwellings for the same money they would otherwise pay for squalid surroundings. With this object in view, he renounced all idea of making his enterprise a very profitable one, gratuitously placing, in fact, at the service of his workmen the creative power of his enormous capital and the benefit of his great intelligence. At the same time, he protected his own interests, and those of social peace and public order; for under improper conditions of existence, well regulated family life cannot be expected. And it is undoubtedly true that the love of work and the sense of duty take root on the domestic hearth, from whence, therefore, spring both the well-being of the individual and of the community.

Mr. Alfred Krupp was always strongly opposed to any plan which provided for the gradual acquisition by workmen of dwellings erected by their master. This system has been very generally advocated, and, to those who do not thoroughly understand the question, it appears very attractive. But it is one which should never be followed in the suburbs of crowded cities, in densely populated countries, where great numbers of workmen engaged in different industries and belonging to different trades are gathered. In a few years, many houses would surely pass into alien hands, and fresh capital would have to be invested to supply their places. Besides which, dangerous elements, calculated to poison the sound moral character of the community, would be likely to gain a footing. It is important that the employer should also remain the landlord, for only in that way can he secure the maintenance of order and cleanliness, and, in short, of the physical and moral health of the population. It also enables him to undertake educational work and to bring up about his factory a set of industrious, sober workmen, in every way respectable and perfectly contented with their lot in life.

Owing to the high price of land and other local difficulties, the cottage system, according to which the house of each family is isolated and is surrounded by a garden, has, as a rule, been found impracticable at Essen. It is a plan which in addition to being a very expensive one, has another drawback, namely, that of greatly increasing distances. Many of the workmen thus obliged to occupy dwellings remote from the factory would lose much time and strength in going there and returning, and in some cases would not even be able to take their mid-day meal at home. For these reasons it was found expedient to build large tenement houses several storeys in height. But it was strictly laid down that the different apartments should be completely detached from each other.

The workmen's colonies at Essen are, as a rule, situated at about fifteen minutes' walk from the factory. Built on salubrious ground, they are intersected by wide streets, and are abundantly supplied with gas and water. The factory administration controls the police and fire departments, and also supervises all necessary disinfecting, cleaning of sewers, &c.

Kronenberg, the largest and handsomest of Krupp's colonies, covers 21 hectares (over 50 acres) of ground, and contains 226 large four-storey stone houses, rendered very light and airy by being separated from one another on all sides by open spaces, 20 metres in width. Each house has a small garden and a grass plot, affording space for drying and bleaching clothes. Broad streets planted with linden trees run lengthwise and crosswise in the colony, at both ends of which schoolhouses have been erected. At the southern end stands the Protestant church with its parsonage, and also a station of the most important railroad in the Essen district. A number of branch shops belonging to Krupp's supply-stores, the organisation of which will be later considered, are scattered about the colony.

In the market, which occupies a central position, fruit, meat, vegetables, and other household necessities, are on every alternate day exposed for sale. On one side of this market-place stands an immense building, containing a restaurant, a library and reading-room, a hall for the reunions of different societies, and another larger hall seating 1500 persons, which is surrounded by galleries and is utilised for occasional gymnastic and theatrical performances. On the opposite side of the market place and in the very heart of Kronenberg is a large well-kept park, in fair weather a gathering-place for both old and young.

At a few minutes distance from Kronenberg lies Schederhof, the colony next in size, which has a population of 4000. The houses are constructed on the same plan as those in Kronenberg, but unfortunately there are no gardens or trees to be seen, the numerous underground waterpipes having forbidden their being planted. The colony possesses, however, a common bleaching-ground of two acres and a large park. It boasts also of all the necessary modern hygienic conveniences with which Kronenberg is provided. One of its streets is lined with seventy houses which are different from the rest. These smaller dwellings were, early in the seventies, erected in haste, to supply a suddenly increased demand for house room. Some of them are still let at very low rents to a few of the poorer workmen, while the others are occupied, entirely free of charge, by the widows of workmen.

MARKETING IN SCHEDERHOF

Kronenberg and Schederhof, as well as the smaller colonies of West-End and Nordhof, directly adjoin the works. But before reaching the settlement of Baumhof (Dreilinden) the distance of a quarter of a mile must be covered. This walk is taken on a good road running through an open country. This colony, thanks to its more rural situation, has been able to assume a different character from the others. The barrack system is here abandoned, and the outside appearance of the houses lends the streets a handsomer and more diversified effect. Each house has a little garden, and some of them are provided with an extra bit of land where pigs, goats, or poultry may be kept. They now number 158 and shelter about 900 people, being inhabited by overseers and skilled workmen with their families.

KRUPP'S OFFICIALS' QUARTERS (HOHENZOLLERN STREET)

A visitor to Dreilinden will not fail to give a look to a wide street called "Hohenzollern" which branches off Kettwig Avenue, the "Unter den Linden" of Essen. This beautiful street, made only a few years since, also belongs to the Krupp firm. Its pretty houses, ornamented by verandahs and surrounded by gardens, are rented only to the higher employés of the firm, and are by them pronounced very comfortable and convenient.

In Krupp's workmen's houses every tenant signs a lease embodying certain household regulations. Special officials are charged to see that these rules are observed, and on their daily rounds to note all irregularities.

Tenants are obliged to admit the officers of the tenement administration into their apartments at any time. Sub-letting is forbidden, and with regard to boarders, so strict a surveillance is exercised that in 1892, for instance, there were only 149 in 3700 tenements.

In Krupp's tenements, despite the strict household regulations which govern not only sanitary matters but also extend to the private conduct of both young and old, but few changes of residence occur, a state of things certainly speaking well for both officers and workmen. Moreover, the demand for these lodgings is so great that, as a rule, they can only be accorded to workmen who have served ten years. This shows that the strict regulations are not found objectionable. Indeed, on the contrary, they are welcomed by the older and more experienced men, as wise and beneficial precautions. This, of course, would not be the case did not the employer, by displaying tact and justice, inspire a feeling of perfect confidence. Thus is the difficult problem of lodging workmen happily solved. And the employer earns his reward by attaching to his person and to his enterprise a set of healthy, industrious workmen, content with their lot in life and devoted to their duty ; but, on the other hand, he must reconcile himself to receiving a very low rate of interest on the capital invested. The Krupp tenement administration handles large sums of money. Not less than 12¼ million marks (nearly £600,000) have now been invested in the buildings, and the annual expense for the colonies amounts to 228,000 marks (£10,800). The annual receipts for rents are 484,675 marks (£23,000), showing an interest of only 2·1 per cent. on the principal, without counting the cost of wear and tear.

In 1892 Krupp's employés and their families were, with regard to residence, divided as follows : 15,300 lived in houses of their own, 25,800 were tenants of the administration, and 47,000 were the tenants of other proprietors.

The present owner of the factory has, in showing solicitude as to the lodging of his workmen, continued to follow the time-honoured policy of the firm, and has further developed the work by building the model settlement of Holsterhausen. He has also been inspired by a desire to test that system, according to which the workman is enabled gradually to become the owner of the house he inhabits: and in 1889 he set aside half a million marks (£23,800) for that object. Any steady workman, or petty official, who wishes to build or purchase a house, is allowed to borrow the necessary sum at 3 per cent. interest, provided he can make a first payment of at least 300 marks (£15) from his own resources. The capital of the loan must be paid off within a period of twenty-five years by instalments, which are deducted from the wages. The firm lets it be understood that only in extreme cases will it use its right to throw up the contract. But such is the confidence placed by the workmen in the administration of the factory, that the capital set aside does not suffice for the applications made. Between seventy and eighty workmen have already by this plan become the owners of their dwellings, those living at a distance from the factory, near the lonely iron-mines, having been especially benefited by the loans.

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In providing lodgings for workmen's families, the Krupp firm had not yet supplied all needs. For many of the workmen are not married, and others, who are not natives of Essen, have left their families at home. In order to supply such men with suitable board and lodging at a low price, Mr. Alfred Krupp some thirty years ago built, in close proximity to the factory, a large barrack called the *ménage*, which was in 1874 inhabited by 1800 men, and which now contains on an average about 800. All single workmen receiving small wages, if not housed by near relations, are compelled to become members of the *ménage*, which measure has proved to be a very wise one.

This solid five-storey barrack forms a square of from 60 to 70 metres length, open on one side. Exterior vaulted corridors, running all round the house, give access to bed-rooms calculated to hold ten men each. At the end of both wings, the necessary wash-rooms and closets are placed. The open side of the square is occupied by two large halls, one of which serves as a dining and refreshment room, while the other contains the kitchen, store-room and wash-room. In the front part of the barrack are some comfortably heated and furnished sitting-rooms, where newspapers can be found. The inmates of the house have also at their disposal a small library, a billiard-table, and a bowling-alley.

This vast *ménage* is of course governed by strict rules. Each room has its monitor, and order is further enforced by a general manager and several overseers. A number of watchmen and firemen are also stationed on the premises. No seekers of quarrels, loungers, drunkards, nor sufferers from loathsome diseases, are tolerated, and should any such cases creep in, the other inmates are expected to report them. A printed code of rules, pasted on the walls, states the rights and duties of the boarders and the limits of the authority vested in the manager.

The kitchen of the *ménage* is a model of its kind. A different bill of fare for dinner and for supper is given every day in the week; the food being somewhat varied according to the season. In cooking, the most minute care and the strictest hygienic rules are observed; the exact quantities of the various articles used in preparing different dishes being specified in a set of printed rules. Large steam cooking-apparatus, on the Becker system, which prevent burning and also evaporation, serve to prepare the meals. These, thanks to the excellence of the apparatus mentioned, and to the careful examination of all material, are sufficiently appetising to gratify even a delicate palate.

Each man's portion of meat at dinner is 200 grammes (7 oz.), and upon the consumption of the vegetables, bountifully served in huge dishes, no limit is placed. Five times a week the supper consists of a soup of rice, barley or potatoes, each man receiving on Mondays an addition of 100 grammes (3·5 oz.) of sausage. On Saturdays herrings and potatoes are given, and on Wednesdays potatoes with gravy and liver sausages constitute the best supper of the week. On Sunday mornings, every boarder gets a weekly ration of 125 grammes (4·4 oz.) of ground coffee and 250 grammes (8·8 oz.) of butter, but must himself provide the bread for his breakfasts. It may be added that throughout the factory are placed boilers from which the necessary hot water for making coffee can be obtained. There are also several stations where, in the morning and in the evening, hot coffee, already made, can be obtained at the rate of 2 pfennigs for ¼ litre (0·1 gallon for ¼ penny). Finally all inmates of the *ménage* are entitled to a clean towel every Sunday, and to clean bed-clothes once in three weeks.

For all this, the adult workman pays but 80 pfennigs (10d.) a day, the boys and apprentices 60 pfennigs (5½d.). Of course it is only thanks to the great number of its inmates that the *ménage* is enabled to cover expenses: and there is no surplus for amortisation, or for paying interest on the capital invested.

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As supplementary to the *ménage*, there has recently been opened, near the colony of Schederhof, a boarding-house for unmarried employés. This institution owes its existence to the present head of the firm, who wished to give the better paid and more intelligent workmen an opportunity of living in a sort of club-house where they might, if found practicable, share the expenses, and enjoy a style of living somewhat superior to that of the *ménage*. He also thought that all the more superior men would derive benefit from thus being brought into close contact with one another. The inhabitants of this house may be considered one large family, of which the head is the manager of the establishment, who is chosen from among their own number by the other members. This manager watches over the inventory of the house, sees that order is maintained, and keeps the accounts. Each of the boarders pays weekly his share of a sum of money, the total amount of which is decided upon by their community. The bills of fare are planned by the manager, aided by a female housekeeper, who is also chosen by the workmen, and who, in addition to taking charge of the kitchen, cleans the house and does the washing.

BACHELORS' HOME

This co-operative boarding house is a handsome three-storey building, and is surrounded by a small garden. Besides twenty simply furnished bedrooms, all of which can be heated, and which hold either one or two beds, it contains a large hall, serving both as refectory and parlour, two well lit and furnished reading- and writing-rooms, also kitchen, pantries, cellar, laundry, housekeeper's room, closets, washing- and bath-rooms. The furnishings of the house are of good quality, and are suitable to the needs of well-paid workmen. Each inmate pays a monthly rent of from 7 to 9 marks (7s. to 9s.).

The house had, when the writer visited it, only been open for two weeks. Its newly elected manager was a middle-aged workman, and an apparently very capable workman's wife was the housekeeper. In spite of the latter's declaration that the new machine did not yet run smoothly, the impression produced by this institution was an excellent one, and its members appeared to be well pleased. Time will show whether the results obtained correspond with the hopes entertained by the founder, and whether they will justify a continuance of the system.

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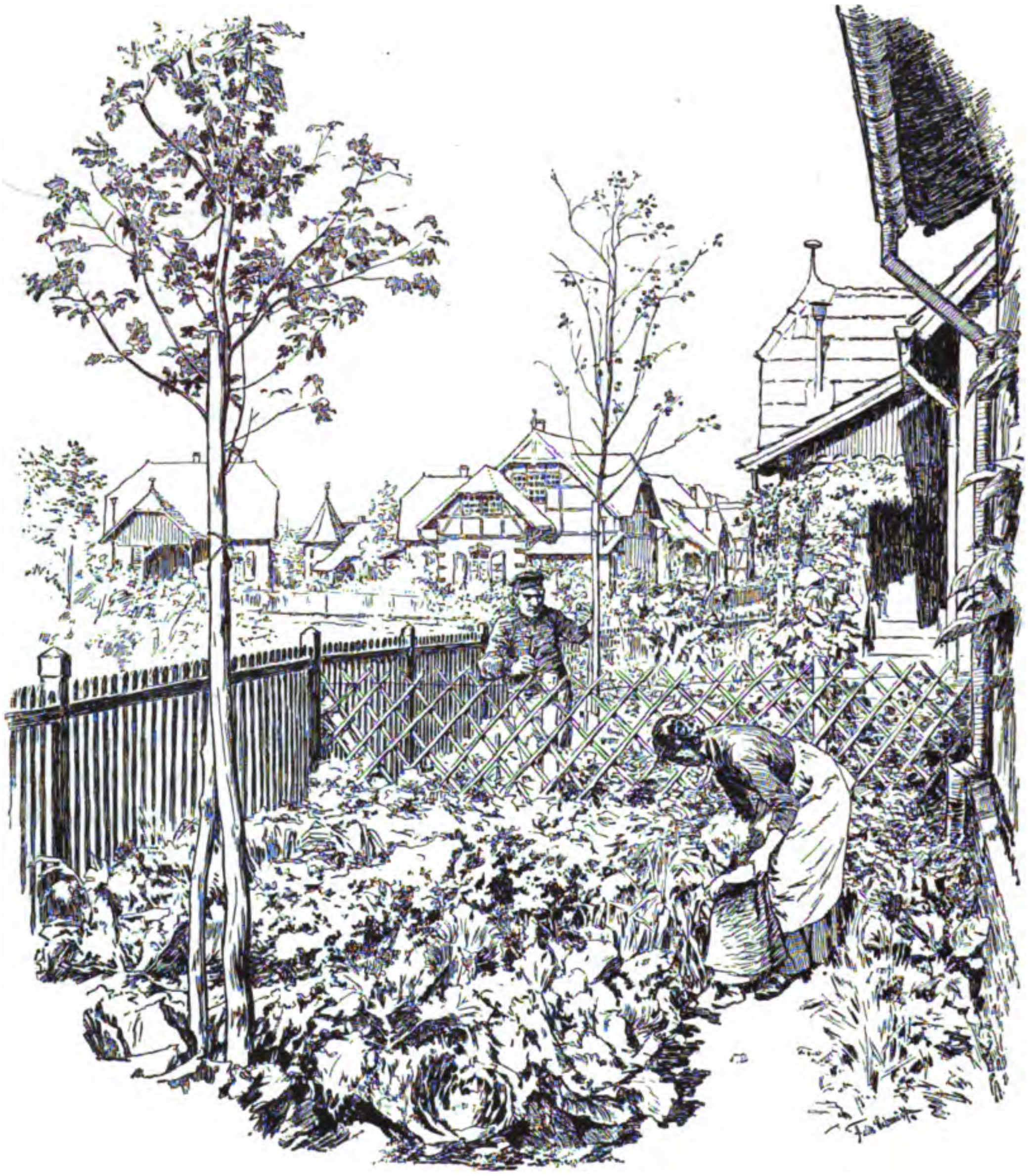
Far from the noise and smoke of the factory, and near the beautiful valley of the Ruhr, in a really idyllic site, between a little wood of beech trees and an expanse of cultivated fields, is a recently opened home for old and disabled workmen. In this refuge, called the Altenhof, men who have grown grey in harness, or who have exhausted their strength in the service of the factory, reap the reward of their faithfulness and good behaviour by being sheltered from all cares and enabled to enjoy peace and rest. This work of philanthropy was planned by Mr. Alfred Krupp, who purchased the ground but died before beginning to build. His son, however, became at once ardently interested in this scheme of his father's. On that memorable day when the monument of Alfred Krupp, erected by his employés, was unveiled, and after one of the workmen, speaking for his comrades, had in simple but touching words, expressed the love and gratitude they bore their late master, Mr. F. A. Krupp addressed the assemblage, announcing that in memory of the day a new colony, to be appropriately named Altenhof (old men's home), would be inaugurated. At the same time he placed half a million marks in the hands of the board of directors, for the purpose of building on the ground selected by his father pretty little houses surrounded by gardens, and adapted to hold one family each, which were to be given to aged or disabled workmen, or to workmen's widows, rent free for life. Mr. F. A. Krupp personally supervised the construction of these houses, and eighteen months later twenty-five of them were ready for occupation. At present Altenhof contains one hundred and twenty-five little homes.

Each of them has on the ground floor a sitting-room and a kitchen ; on the storey above, either one or two bed-chambers ; in addition to these rooms, a cellar and an attic, while a pretty porch and open verandah make the front entrance attractive. A little garden surrounds each cottage. They are not all, however, exactly alike. In order to render the general effect of the colony less monotonous their exteriors have been varied in design, and here and there double houses are placed between the smaller ones. And in laying out the gardens and streets also stiffness has been avoided. But the artist to whom this book owes its illustrations describes the attractiveness of Altenhof better than the writer can hope to do in words. In an open square, in the centre of the colony, there is a branch of Krupp's supply-stores, and also a public kitchen for the accommodation of such persons as are for some reason unable to cook at home.

The writer had quite lately, on the last day of 1894, the pleasure of visiting the Altenhof. It wore a heavy mantle of dazzling snow, with which contrasted the warm tints of the wooden cottages, whose many little gables glittered in the afternoon sun. The streets were almost empty, but a few old people were to be seen at their doors. He scraped acquaintance with an elderly dame, who conducted him into her apartment, on the upper floor of one of the larger houses. She was a widow who, in this spacious chamber, surrounded by all her belongings, seemed quite content. But one thing troubled her, there was no place in the room for her chief pride—a large trunk. This receptacle of invaluable treasures ornamented the corridor, and to complete its resemblance to a Chinese travelling cart it only required wheels. Before the writer left, the worthy woman begged him to grant her a favour : " Herr Krupp has given me and all the others so much pleasure by his Christmas presents. I don't know how to thank him! When you see him, will you do so in my name ? " The promise given her shall now be fulfilled, and the writer here reports to the founder and protector of Altenhof the thanks and blessings of the working man's widow.

The ground floor of this house was occupied by a somewhat decrepit and rather unsociable couple. Of the pretty cottage opposite sole possession was had by a still hale and hearty pair, who were proud to show their



IN COLONY ALTENHOF

domain. Every nook was scrupulously clean, and all was as tidy as possible. However, the writer was strictly forbidden to glance at the corner where the faucet was placed. The running water had sprinkled and slightly spotted the wall, but "father was going to paint it over nicely, and in a few days it would look all right again." The writer told the old couple that he trusted they might for many years to come enjoy their handsome home together. "Oh!" they cried, "that is what we hope, we are so very happy." "Then you feel grateful to Herr Krupp?" "Ah! we cannot tell you how grateful we are. Unfortunately we are unable to thank him personally as we long to do, but we pray for him every evening."

A visit to Altenhof leaves on the mind a very pleasant impression. It is there demonstrated in a tangible way, that, in spite of what pessimists may urge to the contrary, it is possible for the relations between master and men to be thoroughly cordial; provided, however, that the former is genuinely interested in the well-being of his employés, and knows how to keep faith with them.

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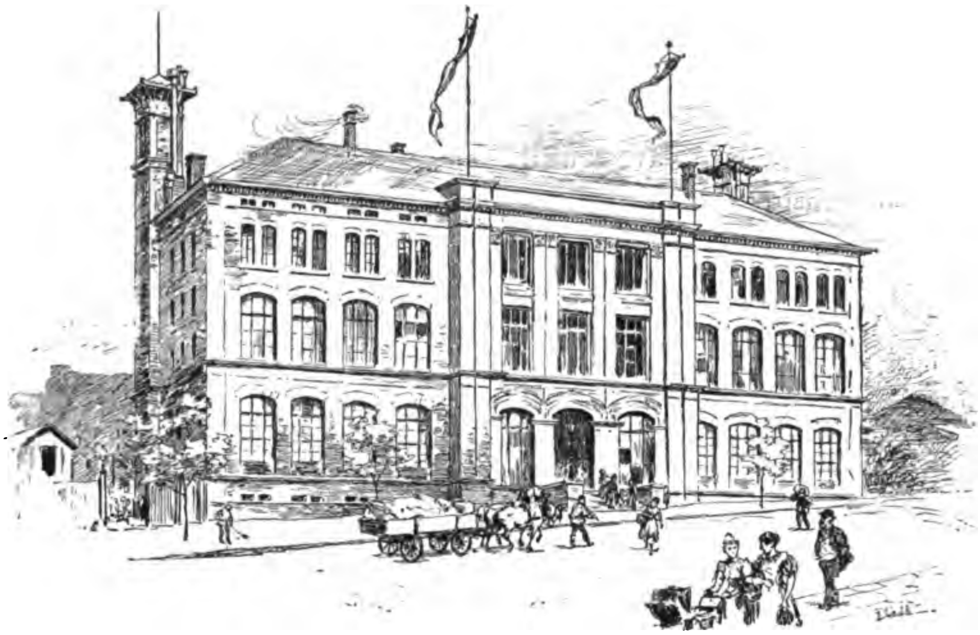
The Krupp firm has not confined its efforts to comfortably housing all its people. It has also interested itself in enabling them to feed and clothe themselves, and to furnish their homes at reasonable prices. For this purpose it established supply-stores. Renouncing all profit, the firm thus offered its employés an opportunity of purchasing all necessary articles at the lowest wholesale prices. In order to cure the workmen of the bad habit of buying on credit, and so to teach them economy, a rule was made that the stores should sell only for cash.

The enterprise had, in its early days, much trouble to contend with. In spite of the measures taken to exclude them, a great many outside customers, attracted by the low prices of the merchandise, contrived to supply their needs at Krupp's supply-stores. This exasperated the shopkeepers of Essen, who showed their hostility in many ways, and finally succeeded in having the stores taxed. To this, the firm replied by opening the stores to everybody, and affixing prices which were not lower than those asked in the best shops of the town, the customer only reaping the advantage of being absolutely certain to get first-rate articles. The stores have since that time, like any other well-managed commercial establishment, made a net profit. But this is, by an ingenious system of rebate, returned in cash every year about the middle of December, to all customers who are among Krupp's employés. To effect this, each one of them is furnished with a stamped pass book in which all purchases are set down in such a way as to render fraud almost impossible. As a matter of course, this system gives the administration of the stores much extra work, but the plan has worked well and is likely to be maintained. For the last few years, the number of account books presented has exceeded 11,000. Shortly before Christmas, the holders of these books received a return of between 5 and 6 per cent. on their accounts, which little present, coming at such a season, was doubly welcome.



MAIN BUILDING OF THE SUPPLY-STORES

The main store of the institution is in the Ostfeldstrasse of Essen, behind the new Krupp monument; and is a four-storey building with a frontage of 60 metres (197 ft.), and a depth of 31 metres (102 ft.). In its different departments, all the needs of a modest household can be supplied. From morning to night people are coming and going, and the whole store is as busy as a bee-hive. In addition to this great bazaar, numerous branch stores have been established in the town of Essen, in the different workmen's colonies, and also in the neighbourhood of the mines.

In the rear of the main building is the warehouse, another four-storey building, 60 metres in width by 16 in depth (197 ft. by 52 ft.), furnished on either side with a platform for the service of the railways which terminate there. In a separated division of this warehouse, a coffee-burning apparatus and an ingenious coffee-sorting machine are in operation.

A subterranean vault contains a reservoir for kerosene, capable of holding nearly 50,000 litres (11,000 gallons) and into which the oil is directly emptied from the cars. Finally, beneath a hill planted with trees, which rises behind the bazaar, are placed the cellars, where a superintendent and nine workmen are kept busy. An average of about 500 bottles of wine per day is sold.

An immense amount of business is done by the supply-stores. Colonial products are the most important items, and together with potatoes and coal, are sold in as many as fifteen shops. Of coffee for instance, 200,000 kilogrammes (440,000 lbs.) per annum are sold, a quantity which, according to the official statistics of Germany, suffices for 80,000 of its inhabitants. According to the same standard, the amount of sugar sold would suffice for 40,000 persons.

The sale of bread is in importance second only to that of coffee. All popular kinds are made, and must, like everything else, be paid for in cash. The large new bakery, built by the factory near Schederhof, is fitted with all the latest improvements and is well worth a visit. It has eleven iron water-heated ovens, and a large oven of porous stone for baking black bread (Pumpernickel); also four kneading machines. A force of twenty-nine workmen turns out daily, in addition to 5500 kilogrammes (12,100 lbs.) of bread, 10,000 rolls, in a great variety of forms and sizes, the whole product being of excellent quality.

Butcher's meat, also, may be bought in several branch stores, which are open to all comers. The quantity of it sold is about sufficient to provide a town of 25,000 inhabitants. The animals are killed in the municipal slaughter-house of Essen, the dividing and other treatment take place in two Krupp butcheries, one of which is on the Limbeck road, the other at Altendorf, in the immediate vicinity of Kronenberg. They are provided with all the most modern apparatus for refrigerative purposes, smoking, corning and sausage-making; and their shining machines and caldrons show that the most scrupulous cleanliness is observed, a condition of things still further emphasised by the fact that even on a hot summer's day there is no disagreeable odour perceptible. In one of these shops a visitor's

THE CASINO

attention is sure to be attracted by a gigantic steam-heated cauldron, in which roll about things resembling young seals. In fact, however, they are marvellous, elsewhere unknown, products of sausageology called Schwartenmagen.

A number of restaurants are, under the direction of the firm, capitally managed. In addition to those of the administration building and the *Ménage*, there is also a restaurant in each colony. One of them, the famous Krupp *café*, situated in the lovely valley of the Ruhr, near the waterworks, is resorted to by hundreds of people belonging to all classes of Essen society. The quantity of beer sold by the firm through these different establishments is as much as 4000 litres (900 gallons) a day. It must, however, be added that three-quarters of this amount is a very mild brown beer—not lager—and, moreover, that the rebate system does not apply to drinks.

The Essener Hof hotel, distinguished in Bædeker's guide-book by a star, is also included in Krupp's domain. Of this unpretentious but thoroughly comfortable house, which is managed by a capable, well-mannered landlord, all those who stop there retain pleasant recollections. Its dining- and drawing-rooms open on a fine park-like garden, on the opposite side of which are the vine-framed verandahs of Krupp's employés' casino, and also the gymnastic and fencing halls.

The sales of the supply-stores are not confined to alimentary articles. There are two large tailors' shops, and there is one shoe shop where shoes are made to order and repairing is done. In fact, with their different annexes, among which may be mentioned a plant for making ice artificially, a brush factory, supplying a number of partially disabled men with work, an ironing shop, various stations where coffee is sold, and weekly markets for fruits and vegetables, the stores are prepared to supply all the needs of a modern manufacturing town of 50,000 inhabitants. They have completely answered the purpose for which their generous and intelligent founder intended them, that being to furnish all employés of the factory, and more particularly the workmen, with good merchandise at low prices. And at the same time, by the ingenious rebate system explained above, the stores have been to Krupp's workmen a real savings' bank.

Short and imperfect as this account may be, it will still suffice to show that the philanthropic institutions established by the Krupp factory equal, in their own way, the industrial products which have made its name all the world over justly famous. Thanks to the pecuniary sacrifices of a generous master, every workman of Krupp's is, with all his family, insured against the vicissitudes of the future, whether death, illness, or old age. The lodgings which are placed at his disposal secure him a comfortable home, and the supply-stores furnish him at the lowest prices with everything he requires, and, by requiring him to pay cash for all his purchases, protect him from speculators and usurers, those fatal parasites of the working classes.

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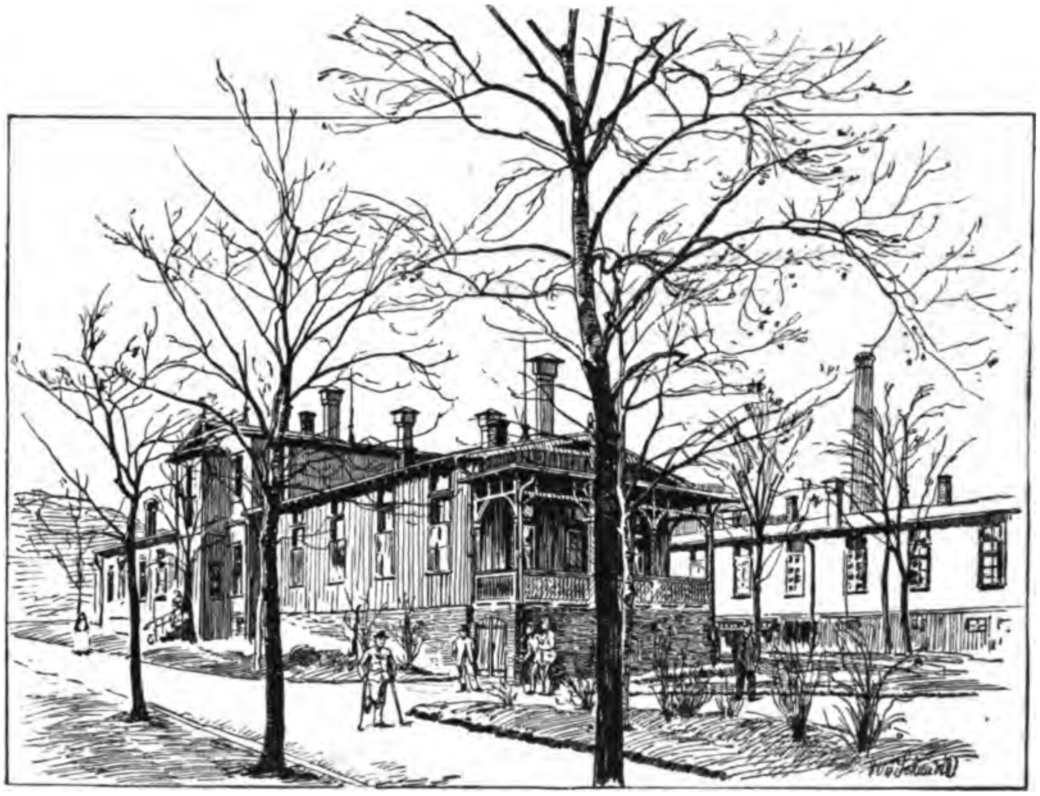
In addition to the three important groups of beneficial institutions already described, many other proofs of Krupp's intelligent solicitude exist. To hygienic precautions, for instance, the greatest attention has been paid. These are controlled by a board of health, consisting of several physicians and a number of the factory's employés. This board prescribes and executes all measures essential to the preservation of the public health, takes especial care to guard against the spread of epidemics, attends to the necessary disinfection of dwellings, removal of all infectious matter, &c. Minute statistics report all cases of disease and the general sanitary condition prevailing throughout Krupp's domain.

In a former chapter of this volume Krupp's waterworks (of all in Germany the fifth in size) have already been described. They are only here mentioned with reference to the quantity of water used in the interests of cleanliness. There are more than 400 stationary washstands distributed between the *Ménage* and the different workshops. In the factory, particularly in the metallurgical workshops, are numbers of shower-baths, enabling the men on quitting work to cleanse themselves quickly and gratuitously. All the closets, which number more than 400, are furnished with running water.

Drinking-water is supplied by a system of pipes connecting with the municipal water-pipes of Essen, and is distributed through the workshops of the factory by 150 automatically closing faucets. This water is at regular intervals analysed and examined by microscope in a special laboratory. In the summer of 1893, on account of an alarm of cholera, all the shops were provided with ingeniously contrived apparatus furnishing boiled drinking-water, slightly acidulated and cooled by ice.

A walk of ten minutes from the main gate of the factory, or from the centre of Essen, brings one to Krupp's Hospital, situated on a large plot of ground in the newly built south-western portion of the town. Its row of green pavilions, standing on gently sloping grounds, ornamented by tall trees and beds of flowers, forms a pleasing, although not an imposing, picture.



AT KRUPP'S HOSPITAL

Five pavilions of 45 metres (147½ feet) in length, containing thirty beds each, stand parallel to each other, having between them spaces 15 metres (49 feet) wide, the second and the fourth pavilions being somewhat further back than the rest. Before the second one stands yet another pavilion, which is larger, and has two halls, also a broad enclosed verandah, where such patients as are able to get up spend their days. This pavilion is connected with the administration building by a covered passage-way and with the one where stores are kept, both of which constructions are placed still further forward. In the porter's lodge, at the entrance of the grounds, there is a reception-room; also another room where ambulance patients are cared for. The Morgue, placed in a corner where trees and bushes conceal it, has, in order to facilitate the quick removal of the dead, one exit, which opens directly on the street.

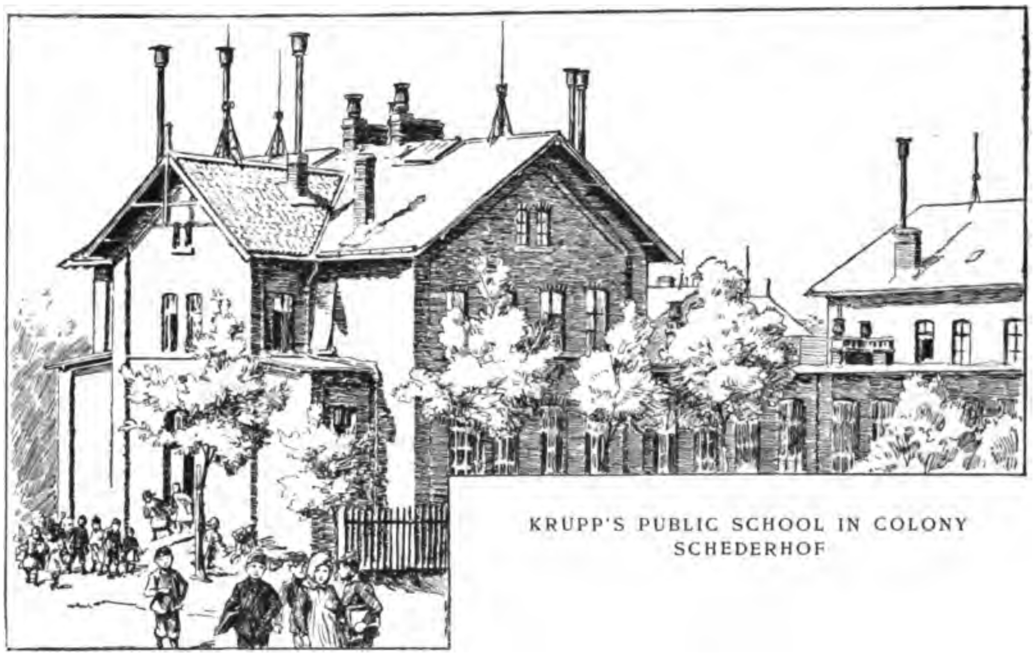
The hospital receives not only all persons connected with Krupp's factory, but also patients of both sexes and of all ages, provided they reside either in the town or suburbs of Essen. The prices charged them vary from 1·5 marks (18d.) per day for adults down to 0·4 marks (5d.) per day for infants. In 1886 Herr F. A. Krupp generously created a special fund of 40,000 marks (£8900), from the interest of which the sick wives or children of his workmen are assisted to make these payments. When the writer visited the hospital most of its departments contained but few patients. Only in the diphtheria ward was there much work to be done. As he entered it, a nurse was carrying a handsome child, three years of age, from the operating room to his bed, while the physician, who had just performed tracheotomy, followed. Let us trust that the poor little sufferer was saved from the dreadful disease.

In addition to this hospital the Krupp firm has built two others, for the treatment of epidemic diseases. These also are wooden constructions. One of them stands on a hill south of Schederhof, and, divided between two large pavilions of two rooms each, has 72 beds. The other on the opposite side of the factory is also on high ground, and is surrounded by fields. It has five pavilions, of four rooms each, from four to six beds being placed in every room. Both these hospitals have annexes containing all the appurtenances demanded by modern medical and surgical science.

In conclusion, it may be added that in various places within the factory there are bandaging stations, where in case of accident immediate aid is given at all hours of the day and night.

This account of Krupp's benevolent institutions is already a long one, but to complete it, some mention of the schools must be made.

Alfred Krupp's first step in this direction was the establishing of public schools in his colonies, and in those parts of Essen which are chiefly inhabited by his workmen. He built commodious schoolhouses, and placed them gratuitously at the disposal of the communities. And choosing a position midway between Kronenberg and Schederhof, he also founded a private school of sixteen classes, which is entirely supported by the firm, and where about 1100 children belonging to those two colonies receive their first instruction. This school is both Catholic and Protestant, its teachers being equally divided between the two faiths, while among the children the Protestant element slightly preponderates.



KRUPP'S PUBLIC SCHOOL IN COLONY SCHEDERHOF

Except during vacation time the passer-by will at noon always see the pupils of Krupp's school marching home in classes, led by their teachers. Instead of rushing noisily out of school to run wild and shout in the streets, they must walk in an orderly manner, and are conducted by the teachers to the neighbourhood of their homes. This is an excellent plan, and one for which parents are very grateful, but is of course a measure only practicable in a place where the children do not live at great distances.

The grounds of this schoolhouse, which occupy an area of about half a hectar (1¼ acre) in extent, are entirely fenced in. A layer of slag and gravel keeps them dry, and they are partly shaded by linden trees. The two main buildings, substantially built of brick, are both two storeys in height.

One of them contains four, the other eight class-rooms, all of 10 metres length, 7 metres width, and 5 metres height (32·8 by 23 by 16·4 feet). In addition to these two buildings, another, which was formerly a dwelling-house, has been altered to afford space for four more class-rooms. In erecting the buildings, and in furnishing, heating, and ventilating the class-rooms, all pedagogic and hygienic requirements have been carefully considered. And it is a pleasure to walk through the carefully kept school gardens, set out with useful and decorative plants, destined to be used for object-lessons in botany.

Whilst Krupp actively assisted public schools, he also endeavoured to fill what is a great void in the present system of educating the working classes. For this almost totally neglects the instruction of growing girls in the duties of a housewife: and this is a matter of which the importance can hardly be exaggerated. All observers who have interested themselves in the condition of the poorer classes have seen how much of their misery and demoralisation springs from the incapacity of the women. In a modest household, with very limited resources, the task of a housekeeper, wife, and mother becomes doubly difficult. But how many young girls, who marry thoughtlessly, quite fail to realise this! There are but few of them who understand, that the workman who brings home wages, which are the fruit of hard labour, has the right to exact that his wife shall sensibly and economically use them to make for him and his children a clean, comfortable home. How few girls know that the best way to make a man's own fireside his chief centre of attraction, and to win his confidence and respect, is to make his life pleasant in a peaceful home, where he finds rest after his work, and also that charm which a woman who is devoted to her duty always diffuses about her. Is it not then essential to the promotion of domestic tranquillity, and consequently of public order, that girls should be schooled for their vocation? Surely no institutions are more useful than those where, by practical lessons, they learn their future duties and are by precept and example taught to be economical and industrious.

By such ideas was Mr. Alfred Krupp animated when, in 1875, he established his industrial school. In its first class are pupils of the primary school with which it is intimately connected. Instruction is given in the schoolrooms already mentioned, also in the Nordhof and the Colony Dreilinden, from two o'clock until four on Wednesday and Saturday afternoons. The girls are taught plain sewing, knitting, crocheting, darning,

&c. Although only the daughters of employés of the factory are admitted, the number of scholars is about two thousand. The forty teachers, who are strictly examined as to their abilities, are mostly the widows of deceased employés. When the writer visited the large school near Kronenberg, he was surprised, as he walked through the corridor, by the silence which prevailed, and supposed that for some reason the instruction was not going on. But he found every seat in the class-rooms filled. The smallest girls were knitting stockings as eagerly as grandmothers, while others crocheted, and the more advanced pupils practised the useful and difficult art of sewing. He was shown several samples of work, and was not chary of his praise. His guide, an employé of the supply-stores, displayed a surprising amount of information about seams and hems. The writer gladly endorsed his favourable judgments, and took pains to learn the language, and to copy the manner of a connoisseur, which attainments he shortly afterwards brought into play.

The children must bring to the school the materials necessary for their work, but are not allowed to take this home in an unfinished condition. They each pay a monthly fee of 20 pfennigs (2½d.), but if they have been well behaved and industrious this money is, after fifteen months, returned to them in a savings' bank book. At Christmas, cakes and confectionery are distributed amongst them, and the best pupils receive prizes. These consist of furnished workboxes, kindly donated and distributed by Frau Krupp, which seem to be a great incentive to diligence and good conduct. It was pretty to see with what pride the successful girls placed those boxes of polished wood before them. And when the writer spoke to one, saying: "So you too, little tot, have got a nice workbox?" the child's eyes beamed with pleasure.

The second class of the industrial school is lodged in a special building, a solid, imposing construction, situated opposite the Essener Hof. In it women and girls over fourteen are taught not only all such feminine handiwork as is useful in a modest household, but also have an opportunity of learning to do work which will enable them to earn a living. Into this class as many outsiders are received as space and the number of teachers permit. They must, however, pay fees, which, although very small, are still double those paid by pupils connected with the factory. Sewing by hand and embroidery are taught in monthly courses of daily lessons, which are of from three to six hours in duration. A course of instruction in machine-sewing and dressmaking lasts for three months.

When the writer visited this school, about two hundred pupils filled the fine lofty rooms devoted to the different branches taught. With the help of his guide and his own newly acquired knowledge of the technicalities of

IN KRUPP'S INDUSTRIAL SCHOOL FOR WOMEN

sewing, he criticised everything in as knowing a manner as if he were a genuine official inspector of schools. He examined the seams, remarked on the artistic effect of the embroideries, and had a newly finished dress tried on for his benefit. He did not stint his praise, nor was it insincere. Of course his part would not have been properly played had he not made a few joking remarks. But these only referred to the enormous sleeves of the model dress, and so hurt no one's feelings. Dame Fashion is a tyrant, and not even a working woman in provincial Essen would venture to disobey her decrees. But it must be confessed that such a woman and her daughter in their Sunday attire widely differ from an artist's ideal of a woman and child, as represented in the beautiful group on Krupp's monument.

On the ground floor of the industrial school there is a room where linen is ironed for the public at low rates ; the real object of its establishment is, however, to teach the art of ironing to the girls and women connected with the factory.

A visitor cannot leave this school without being convinced that it is a practical and intelligently managed institution, and that in its beneficial effects on the common welfare of the workpeople it must fully realise the hopes entertained by its founder.

KRUPP'S HOUSEKEEPING SCHOOL

On the path of domestic instruction a great step forward has recently been taken in the organisation of a housekeeping school. The teachings of this institution, which also was established for the benefit of the daughters of workmen and other employés of the factory, are not confined to feminine handiwork, but are designed to fit girls completely for the management of a modest household. A thorough training in the preparing and cooking of simple food is therefore given. The course of instruction lasts four months, and every two months twelve new pupils are admitted. The girls remain at the school from seven o'clock in the morning until eight o'clock at night, and are obliged to appear neatly and suitably dressed. The lessons are gratuitous, but scholars pay three marks (3*s.*) a month for their food. Very poor pupils are, on application, released from this charge. As a matter of course, under these conditions the institution cannot cover expenses ; the firm, therefore, contributes to it the sum of 15,000 marks (£715) a year.

The schoolhouse, built four years since, is surrounded by a garden, and is situated in the open fields lying between Kronenberg and Schederhof. The writer visited it at noon. At the door he found waiting a crowd of children carrying food baskets and double cups of enamelled iron. The main door opens directly into a large hall, inside which stood another troop of little purveyors. On the one side of this hall long tables were placed, at which a number of men, robust workmen as well as frail veterans, sat eating their dinner. For the school is also a restaurant, the products of the kitchen being thus utilised, while at the same time the pupils' ambition is stimulated by the knowledge that their work will be freely criticised by the customers. Into this eating-house the general public is not admitted. It is open only to widowers and their children, to invalids, to workmen with their families when the mother is ill, and to widows and their children, in case the woman has outside work which prevents her from cooking at home. The price of a dinner is 35 pfennigs (4*d.*), the same as in the *Ménage*, but the bill of fare offers a greater variety of dishes. For destitute persons the factory physicians, also the administrators of the sickness fund, are authorised to order from the housekeeping school meals free of charge.

A few steps distant from the back door of the dining-hall is the main kitchen ; a large room, 12 metres by 8 (39 ft. by 26), lit from the ceiling, which is supported by columns. Although the writer entered it at noon, the busiest hour of the day, there was no rush or confusion. Nor did the unexpected advent of visitors create the slightest disturbance. On the longer sides of the room stand seven cooking stoves, all of them being provided with the necessary utensils and accessories. At each one he found a pupil at work. All the girls cook the same dishes for ten persons. To each one is given the proper quantities of materials, weighed according to the recipes, which are written on slates affixed to the wall by every stove. A head teacher and her three assistants superintend the proceedings, also taste and criticise the dishes when prepared. The scholars take great pride in their work, and it seldom happens that a dish is burned or otherwise spoiled.

The writer being a chemist, he was quite naturally keenly interested in the cooking lessons. The amiable head teacher wished him to examine and admire everything; he found it a pleasure to oblige her, and not a word of her explanations escaped him. After the kitchen he looked at the well stocked pantry, and then repaired to the cellars. There he found casks of sauerkraut and pickled cucumbers, while the long shelves, in rows reaching from the floor to the lofty vaulted ceiling, were laden with glasses and boxes of salted vegetables, sour and sweet preserved fruits. But all this supply was only what remained over from the previous year, and in another month the busy fingers of the pupils would produce a fresh lot.

The writer was not willing to leave without a glance at the schoolrooms. In one of them he found a number of girls busy over household books in which calculations were made, recipes and various practical hints as to the management of a house carefully copied. In another room, mending and darning are taught; but there was no more embroidery or handsome crocheted lace to admire. The pupils in the third division were hard at work washing and ironing.

A walk through the garden ended the writer's visit. Although the season had been very dry, flourishing beds of peas, beans, lettuces, cucumbers and herbs, testified to the conscientious care of the pupils. All these products are, of course, utilised in the kitchen. In a wire-fenced enclosure, a goodly crowd of chickens were enjoying the sunshine; amongst them a fine rooster standing on one leg appeared very conscious of his own importance. Instruction in the care of a poultry-yard naturally forms part of the education of good housekeepers, and the establishment takes pride in never being obliged to purchase a single egg outside.

While the institutions reviewed in this chapter, when compared with the previously described enormous factory and its remarkable productions, may, in contrast, appear almost insignificant, they are still evidences of the same creative genius which developed every branch of the gigantic organism. The Krupp factory would not be what it is, had its owners not understood that the moral and material well-being of workmen is one of the conditions of good production; that it is a master's duty to interest himself in such matters, and that peace and contentment among employés are necessary foundations of prosperous and durable enterprises.

SUPPLY-STORES; DEPARTMENT FOR COLONIAL PRODUCTS

SUPPLEMENT

THE FACTORY IN THE SPRING OF 1897

During the three years which have elapsed since the publication of this book, startling accounts of new enterprises and fresh successes of Krupp's have been noised abroad. Large territories purchased near the Rhine and the Moselle, furnishing the ground for other mining plants, have been mentioned. And it has become known that the signature of the famous foundries and machine-shops established near Magdeburg, founded by Hermann Gruson, was three years since changed to "Fried Krupp Grusonwerk." Even more surprising was the news of Krupp's having assumed control of the shipbuilding yards "Germania" at Kiel, and thus taking a first step into the domain of naval construction. The newspapers and other publications have also given detailed descriptions of important improvements in the manufacture of steel at the Essen works, and it has particularly been stated that Krupp's armour-plates of hardened nickel-steel now surpass anything previously accomplished in that line.

And finally, more than once during these years there has spread through Germany the report of extraordinary donations made, and new organisations formed, for the benefit of Krupp's workmen and other employés.

The writer was, last Easter, invited to inspect personally all these improvements; and although his expectations were great, they were surpassed by reality. He therefore readily yields to the suggestion that he should write a supplement, and briefly depict the development, during the last three years, of Krupp's works.

Beginning his tour where the crude iron required for the manufacture of steel is produced, in addition to the three blast-furnace plants near the Rhine, he saw in course of construction a fourth one, which will be started this autumn. Nearly 1½ kilometres square (370 acres) of ground have been purchased on the left bank of the Rhine, near Rheinhausen, south of Duisburg; and the high structures which are springing up there form already a prominent feature in the landscape. Manufacturing industry has thus obtained a firm foothold on the left bank of the Rhine, where agricultural pursuits were previously dominant. The land has been banked up 1½ metres (5 feet) above the dykes of the river, and three blast furnaces are being built. These are about 60 metres distant from one another, and their crowns, rising 28 metres (92 feet) above the ground, are connected by trestled bridges. For each furnace, four blast-heaters (Cowper's system) are established at right angles to the furnace-line. Their height is 31 metres (102 feet), and the masonry of each comprises one hundred double car-loads of fireproof bricks. The imposing engine-house will contain four blowers for the three furnaces, each blower having a capacity of 1000 cubic metres (35,300 cubic feet) per minute. At some little distance from the furnaces rises a powerful water-tower, which, by means of adjoining pumps, will provide the new plant with not less than 325,000 cubic metres (70 million gallons) of water per day.

Railway tracks laid on high dams communicate with the Rhenish railway system. The ores and other material will, however, mostly reach the plant by water. To this end there is in course of construction, and now nearly completed, a great harbour on the Rhine, boasting a water-wall 12 metres high and over 300 metres long (39 feet by 1000 feet). There will shortly be also erected there, unloading machinery of extraordinary capacity, made according to an American design.

Krupp's entire new plant near Rheinhausen will be of proportions in correspondence with the dimensions given above. It will therefore occupy, perhaps, the first place among modern blast-furnace works in Europe and elsewhere.

In the original works at Essen, numerous additions and improvements, also many new buildings which have been constructed for the administration and the technical offices, all testify that the gigantic organisation flourishes and is spreading in every direction. A new mechanical workshop, 85 metres by 60 (280 feet by 197), especially intended for machinery and assembling guns, may first be mentioned. It stands, visible from afar, on a high hill of slag, at the western end of the colony, facing the workmen's colony, Kronenberg. Like all Krupp's other recently built workshops, it is without upper storeys or galleries, merely consisting of a lofty middle aisle provided with travelling cranes, and with a secondary isle on either side. All tools and cranes in this shop are driven by individual electric motors.

The most important development in the cast-steel factory has been a metallurgical one, which bears the mark of "nickel-steel." This iron alloy, at present everywhere more or less successfully manufactured, has, in the hands of Krupp's metallurgists, by means of systematic improvement of its composition and manner of production, now reached perfection, and is the ideal metal for all constructions. For, not only does it show higher qualities in the tension tests than the best cast-steel, but it also possesses that extreme toughness formerly only obtainable in the sinewy wrought-iron. In this latter respect it may be compared to leather. A piece of deer-skin and a piece of stout linen with selvage intact may equally resist tearing, but if cut a little on the edge, what a difference between them! The linen will quite easily tear from the cut right across. Not so the leather. Its resistance will be very little diminished; the edges of the cut will spread, but the skin will not tear. Krupp's nickel-steel of 65 kilogrammes tensile strength and 44 kilogrammes elastic limit (92,500 lbs. and 62,600 lbs. per square inch) will act in a similar manner. A rod of it having a slight cut may at that place be bent considerably, whilst under the same conditions a rod of common steel would break short. In the autumn of 1896 a board of experts, chiefly consisting of representatives of various railways, was present at a number of tests, including one of a nickel-steel axle for a locomotive. This had been weakened round the middle with a sharp notch made on a lathe. It was tested by dropping on it a ram weighing 1000 kilogrammes (2205 lbs.) from a height which, beginning at 1 metre (39 inches), was increased by half-metres up to 7 metres (23 feet); and not until the fourteenth blow did it break. A similar axle made of the best crucible steel broke at the first blow, which was delivered from a height of 1 metre. Yet in the testing-machine both materials had shown 21 per cent. elongation and 58 per cent. contraction. Such results make it evident that, as all practical metallurgists are well aware, a metal cannot be exhaustively characterised by the testing-machine.

It has, by the tests above described, been ascertained that Krupp's nickel-steel possesses that quality for which, until quite recently, sinewy wrought-iron, even for heavy shafts, was held in high esteem by mechanical and naval engineers—*i.e.*, it does not suddenly break when it has received a transverse crack by overstraining. As the crack widens gradually, it can with proper attention be ascertained if or when such a shaft needs to be replaced. Now, nickel-steel is far superior to wrought-iron, both in tensile strength and elastic limit, the latter being even considerably higher than the tensile strength of wrought-iron. Moreover, with increasing dimensions of pieces of wrought-iron there is a corresponding increase in the danger of unreliable welding. Nickel-steel is therefore incontestably the fittest material for ships' main shafts and for all such parts of machinery as are obliged to withstand extraordinary strain and yet must be made absolutely secure against the possibility of sudden fracture. Its superior qualities are of such importance that its higher price has but little weight in the balance. Indeed, even at present, pieces of nickel-steel in all sizes are worked at Krupp's forges and shops, amongst them crank-shafts up to 50 tons weight, intended for sea-going steamers.

The largest and also the best known product of nickel-steel is Krupp's latest kind of armour-plate. In order to see it manufactured, the writer entered that part of the factory described in chapter xiii. He at once noticed the great changes it had undergone in two years. The large hall of iron and glass, covering 2 hectares (nearly 5 acres), no longer suffices. Several annexes are already finished, while others are in course of construction. Plates of all shapes and sizes, and in every stage of completion, leave only narrow lanes for moving about. A number of finished belt-plates form walls of steel, here is a circle of curved plates, yonder are parts of the armoured shafts which allow protected communication between a ship's turrets and ammunition-rooms. From a little distance sounds like those of Cologne Cathedral's great bell reach the ears. These proceed from the large steel vault of an armoured cupola, on the edge of which workmen are busy with hammer and chisel. All the powerful machine-tools, although their number is much increased, are at work on heavy pieces. At present they are all driven by separate electric motors, as are also the cranes. Their central electric station, established in one of the annexes, now contains three Siemens inner pole-ring dynamos, having a total of 750 horse-power.

When the plates made here are ready for reception, careful tests show that, superior to the product of former years, their face is absolutely invulnerable to the hardest steel tools. This layer of hardened steel reaches to about an inch under the surface, and there very gradually changes to the original material, a soft, tough nickel-steel of extraordinary resistance.

This excellent quality of the plates is the result of the treatment they undergo after they are rolled, which has been developed at Krupp's during these last years and put into practice by marvellous novel appurtenances. No modern armour-piercing shell can drive its point through the skin, hard as pebble, of these plates. Also the fragments of projectiles fired against such plates show that their heads have been completely flattened. It is a matter of the energy saved in the body of the projectile after such action whether it may still be able to punch a hole into the plate in the way a punching-machine will act. At any rate, the upsetting and flattening of the shell's head consumes a very considerable part of its energy and changes it into heat, and this explains why these plates offer a resistance equal to that of common steel plates twice as thick, or wrought-iron armour three times as thick. Besides, each plate as a whole possesses, like leather, a toughness in consequence of which even a number of hits close together fail to crack or break it.

With such results it is easily understood what extraordinary reduction in the dead weight of armour-clads is obtained by the use of this latest product of armour-plate manufacture.

The measures for the benefit of his workmen taken by Krupp during the last two years have kept pace with the development of the cast-steel factory in its metallurgical and mechanical departments. The writer first repaired to the bachelors' home, and was surprised to find a second similar establishment erected near the first one. This new building, which has been occupied for several months and is now filled, is larger and architecturally more elaborate than the old construction. In the beginning considered rather a doubtful venture, this experiment has evidently proved a successful one. When the first house was built, as the unmarried workmen seemed inclined to view the project with disfavour, some difficulty in filling the rooms was experienced. Very soon there was, however, a lively demand for them, for even the young men found out that they enjoyed this mode of life; and it exerted, not only on them, but on the workmen in general, so favourable an influence that an extension of the plan was at once decided upon.

Further out in the country, situated on elevated ground, is an entirely new colony, which, in remembrance of the late Mr. Alfred Krupp, has been named "Alfredshof." Its picturesque streets and squares no visitor can fail to admire, and while in general effect the colony strongly resembles that of Altenhof, described in the last chapter of this book, it soon becomes evident to the observer that the buildings, particularly as regards their external appearance, are far superior to those in the older settlement. Fine gables and bow-windows adorn even the smallest cottages, the architecture of their roofs is most elaborate, and their whitewashed walls are ornamented by brickwork and woodwork of a dark red colour. Each little house has a verandah, and is surrounded by a garden, but no two of them appear to be exactly alike. On a square planted with trees, in the centre of the colony, stands the new four-storey building of the supply-stores, remarkable not only for its imposing exterior, but also for its conveniently planned interior arrangement. This new village certainly presents a great contrast to the monotonous grey lines of unadorned barrack-like houses formerly built for the workmen. In the dwellings at Kronenberg and Schederhof, which were constructed merely with a view to practical convenience, the workmen, it is true, perhaps enjoy as much actual comfort as do those lodged in the pretty cottages at Alfredshof. But surely it is undeniable that artistic and tasteful surroundings, especially amongst a population of workmen, never fail to exert a civilising and educational influence.

The writer took great pleasure in seeing "Altenhof" again. This favourite colony of Mr. F. A. Krupp's now not only covers all the space originally designed for it, but has in some directions even outgrown that limit. By their architecture and grouping, the latest houses show that Krupp's building department has rapidly advanced in skill, and is fast approaching real mastership. Since the writer's last visit to the colony the young trees have grown, the little gardens have developed, and the vines which now shade the pretty verandahs add a finish to the lovely picture presented by this "home for the aged."

At the lower entrance to Altenhof, an almost completed "Convalescents' House" forms a new link in the chain of Krupp's benevolent institutions. Any of his workmen who, after recovering from an illness, require a prolonged rest, can find in this establishment a healthy pleasant abode and suitable board. On the occasion of a visit from H.M. the German Empress, Mr. F. A. Krupp, moreover, created a fund of 300,000 marks (£15,000), designed to enable workmen who, through force of adverse circumstances, are too poor to pay board, to enter the Convalescents' House free of charge. At the time when this donation was made, orders were issued to build a Protestant and a Catholic chapel in Altenhof, so that old and infirm members of the colony who are unfit to walk to more distant churches may be enabled to attend divine service in the colony itself.

At the time of the writer's visit, the Convalescents' House was already roofed, and a hundred industrious hands were busied on its interior arrangement and decoration. The great, three-storeyed, well-proportioned building has, on three sides, verandahs looking out on a pleasing picture of garden, fields, and woods. A newly-made garden, laid out in terraces, covers the slope of the hill. It seemed almost incredible that, only a year since, there had been barren fields where shrubs and flower-beds were now in full bloom. But a twenty-year-old linden, with roots imbedded in its original soil, and not yet planted, reminded the writer that these grounds of Krupp's are under the direction of a race of Titans well used to mastering the forces of nature.

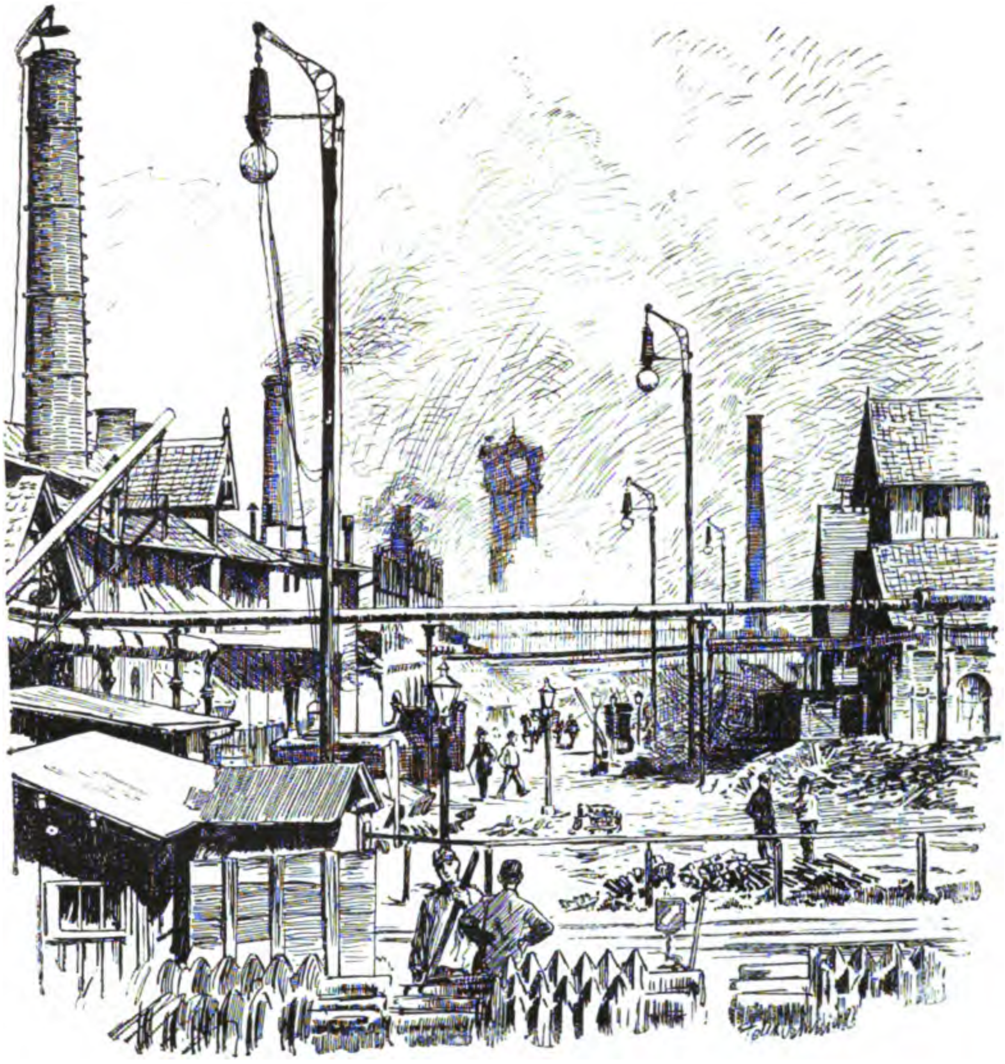
Whilst walking through the workmen's colonies and the workshops, the writer's attention was attracted by a printed notice, posted in various places. This proclamation, made by Mr. F. A. Krupp to his employés and workmen, and dated March 20th 1897, was issued the day before the centennial of Emperor William the First's birth. An extract from it will form a fitting conclusion to these supplementary remarks. It urges all who belong to Krupp's factories to keep ever green the memory of that great, well-beloved monarch, whose noble character and true heart, whose faith and charity, have never been surpassed; and also, in memory of him, to be, "*in joy and in sorrow, in prosperity and in adversity, always loyal to his grandson, the present Emperor and King.*" These words then follow:

"*Of my gratitude to the late Emperor for his fatherly care, particularly as shown in his solicitude for the well-being of working men, it is my desire to now offer a tangible proof. Therefore I have decided—*

"1*st. To place at the disposal of the administration of my works a capital of one million marks. The interest of this sum is to be used in lending a* *helping hand to such of my workpeople as are incapacitated by old age or other causes; that is, in case an addition to the Government aid is needed, and in case the already existing old-age funds or other benevolent funds connected with my works do not provide for such an addition.*

"*2nd. To enlarge by new buildings the colony Altenhof, established for the veterans of my cast-steel factory, in order that a larger number of them may benefit by gratuitous lodging in that settlement.*"

It would surely be superfluous to comment upon this proclamation, for no one who is animated by a spark of philanthropic feeling can fail to be impressed by the generosity which inspired it.



IN THE SOUTHERN QUARTER OF THE WORKS

2nd SUPPLEMENT.

January 1911.

During the 14 years that have elapsed since the publication of the first supplement to the original edition of the above book, the development of the Krupp works has been quite extraordinary. Not only have the Steel works at Essen in the meantime doubled the number of their workmen, but also have the branch establishments acquired by the firm of Krupp, grown to an extent that on the 1st of May 1910 the number of workmen and officials in all the works together amounted to about 69,000.

A distinct landmark in the history of the Steel Works is the year 1903, in as much as in this year the whole of the works, in accordance with the last wishes of its proprietor, Mr. Friedrich Alfred Krupp, deceased on the 22nd of November 1902, were formed into a Joint-Stock Company under the firm of "Fried. Krupp A.G.". This transformation, however, merely meant a change in the form of administration, since the works passed entire into the possession of the testator's eldest daughter Bertha, in whose hands also the shares have remained undevided. On the 15th of October 1906 Miss Bertha Krupp married the Secretary of Legation Dr. Gustav von Bohlen und Halbach, who by an act of grace of the German Emperor became entitled to add to his own the name of "Krupp", he himself and his eldest son.

The following principal data may show this newest history of the works:

1896. Taking over of the management of the Shipbuilding and Engineering Company "Germania" at Kiel-Tegel.

1897. Inauguration of the first blast furnace plant at Rheinhausen.

1899. Purchase of the coal mine "Hannibal" at Bochum.

1902. Completion of the rebuilding of the yard and plant of the "Germania" at Kiel. The Shipbuilding and Engineering Company "Germania" becomes sole property of the firm of Fried. Krupp.

1905. Inauguration of the enlarged blast furnace plant, and the steel shops and rolling mills at the Rheinhausen works which, since 1904, have been named "Friedrich-Alfred-Hütte".

1907. Starting of an electric steel plant at Essen.

1909. Establishment of a new proving ground at Essen.

Along with this enlargement of the different departments of the Works the extension of the welfare institutions kept pace, for it was in these institutions that Friedrich Alfred Krupp during his lifetime was most interested, and the firm has thought it their unvarying duty, to follow up his ideas in developing them.

Some data may elucidate this development:

1894—1899. The workmen's colony "Alfredshof", laid out on the cottage system, is erected to the number of 232 dwellings.

1895—1901. Erection of the colony "Am Brandenbusch" for the workmen employed at the private estate "Hügel".

1897. Foundation of the "Aged and Disabled Workmen's Fund", supplementing the aid rendered by the various other funds, with an original capital of 1,000,000 M. Inauguration of the "Kaiserin-Auguste-Victoria-Convalescents' Home" destined to receive convalescent workmen.

1899. Erection of the first part of the colony "Friedrichshof".
Opening of a circulating library with a stock of about 7500 volumes (at the end of 1910 this had risen to 73,000 volumes).
Foundation of a "Society for the promotion of mental and social culture" (Bildungsverein) which counts at present 3200 members.

1900. Foundation of a "Savings Bank" for workmen and minor officials, which enables them to save money in the way of self-imposed and regular deductions on their wages; on these deposits the firm of Krupp allows them 5 % interest By and by this saving institution has been extended to all branch establishments, at Essen alone it numbers more than 15,000 depositors with a total deposit of 5,300,000 Marks.

1904. First extension of the existing colonies.

The building activity of the firm, resumed in 1894, has developed with more and more animation since the year 1904. It was especially the "Friedrichshof", begun in 1900, that was extended to about 550 dwellings, further the "Alfredshof", which to-day contains nearly 1000 dwellings, finally the "Altenhof" which now nearly has 400 dwellings. Besides, houses for foremen were erected in different quarters of Essen, so that the Steel Works now have at their disposal at Essen more than 6000 dwellings altogether.*)

One of the most important of the recent creations which, thanks to a foundation of Mrs. F. A. Krupp, rose up in connection with the "Kaiserin-Auguste-Victoria-Convalescents' Home" in the "Altenhof" is:

1907—1909 the erection of three more Convalescents' Homes where convalescent or ailing workmen's wives and children also are received.

The whole of the arrangement and the plain yet tasteful outfit of these houses, with their gardens and parks around, placed in quite a picturesque landscape, unite to form surroundings, gay and beautiful, which in connection with the ozonic air of the woods near, are apt to revive and strengthen the weakened forces of the convalescents.

On the following pages are represented a few pictures taken from these houses which may appropriately conclude these supplementary observations.

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*) To these must be added 3000 more dwellings chiefly erected in the different outlying works, during the last 10 years.

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Kaiserin-Auguste-Viktoria-Convalescents' Homes.

Arbour on the Terrace-Side.

View on the Children's and Women's Homes

On the Terrace of the Men's Home No. I.

Parlour in the Men's Home No. II.

Balcony and Veranda in the Women's Home.

Parlour in the Women's Home.

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